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1967 No. 1

The Food of Cod in the North Sea and on West of Scotland Grounds

By BENNET B. RAE
Marine Laboratory, Aberdeen
July 1966

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The Food of Cod in the North Sea and on West of Scotland Grounds

INTRODUCTION

For many years the cod, *Gadus callarias* L. (synonym *G. morhua*), has provided from 40 to 50 % of the total catch of demersal fish from the North Atlantic. Because of its obvious economic importance, the cod has probably been the subject of more research than any other fish, marine or freshwater, with the exception of the herring and the Atlantic salmon. Among the various aspects of research on cod, the food has received attention in a number of regions. Round the British Isles Todd (1905, 1907) examined nearly 700 cod in his study of the food of fishes in the southern North Sea and Graham (1924) dealt with the food of the adult fish in the southern and central North Sea. In Scottish waters Brook (1886) examined the stomachs of 300 cod caught off south-eastern Scotland and Smith (1887–1890) published a detailed account of his investigations in the Firth of Forth, but no comprehensive study of the food of cod in the north-western North Sea or on west of Scotland grounds has yet been attempted. Other papers on the food of cod in the North Atlantic will be referred to at appropriate places throughout this paper.

During the earlier part of the inter-war period (1922-1930) it was customary on Scottish research vessels to note the stomach contents of most fish of economic importance. Naturally cod received considerable attention and with the author's growing interest in the subject these observations were continued intermittently on the research vessels throughout the 1930's and became routine measures after the second war, from 1949 to 1965. Not every catch of cod was investigated in those years, but in most hauls nearly all the cod of 21 cm and upwards were examined, and in exceptionally large catches representative samples covering the size range were handled. Although practice varied over the period of the observations, in general the presence or absence of food in the stomachs was noted and the animals eaten were identified as far as possible to the genus or species. No attempt was made to measure the volumes of the food in the stomachs, although rough estimations were made of the proportions of the different types represented. From this and from the nature of the food generally it became apparent that the individual animals eaten, decapod crustaceans, fish, aphroditid worms and molluscs, were nearly all of an appreciable size and that the food of each successive size-group of cod was characterised by a corresponding increase in the average sizes of the animals preyed upon. Consequently, although the frequencies of occurrence of the various food types in the stomachs do not represent the volumes of these types, they are nevertheless broadly representative of their relative over-all importance, and give a somewhat more accurate indication of the food of cod volumetrically than do corresponding frequency figures for some other species. For example—the small-mouthed lemon sole preys predominantly on polychaetes, many of them long and thin but of a relatively large volume, and on small crustaceans, chiefly amphipods and juvenile eupagurids, which, because of their small size, constitute a relatively insignificant part of the total volume of the stomach contents. The frequency of occurrence of certain types in the food of lemon soles tends, therefore, to give a rather biased impression of the food values, a feature which is not nearly so evident in the cod.

Although the proportions of decapod crustaceans and fish (the two main food types) may vary considerably in individual stomachs, nevertheless the percentages representing their frequency of occurrence may be regarded as reasonably acceptable measures of the overall corresponding volumes.

Later, in the 1950's, it was considered desirable to have some information on the quantities of food eaten at different times of the year and at different times of the day. For this purpose the contents of the stomachs were estimated either as represented by traces or as occupying one-quarter, one-half, three-quarters, or the full capacity of the stomachs.

These observations were carried out and recorded by many former and present members of the Marine Laboratory staff while on sea duty on the Scottish research vessels. Over so long a period and considering the

many research workers involved it is perhaps remarkable testimony to the accuracy of these observations on the food of cod that similar results recur so frequently throughout the records from different localities within the area investigated.

Over the period 1922–1965 the stomachs of more than 15,000 cod were examined. As far as possible the observations were made in two size-groups, 21–50 cm and 51 cm and over (in some early records individual lengths were not recorded), mainly with a view to distinguishing between immature cod and adult fish, although the two categories naturally overlap to some extent. The sex and maturity of many fish were also recorded.

About 13,000 of the cod were caught by otter trawl, small numbers by seine-net and great-line and over a thousand by hand-line or ripper off the mouth of the River Dee at Aberdeen. With the exception of the ripper-

TABLE I

FEEDING OF COD, NORTH SEA AND WEST OF SCOTLAND, 1921—1965; NUMBERS EXAMINED AND NUMBERS WITH EMPTY STOMACHS (ALSO EXPRESSED AS PERCENTAGES) IN EACH MONTH

	21-50 cm		51 cm and upwards		Various Sizes		Totals	
	Exam.	Empty	Exam.	Empty	Exam.	Empty	Exam.	Empty
January	287	45	337	43	69	8	693	96
%		15·7		12·8		11·6		13·9
February	513	49	360	59	17	1	890	109
%		9·6		16·4		5·9		12·3
March	603	114	545	134	41	5	1,189	253
%		18·9		24·6		12·2		21·3
April	289	61	266	46	273	70	828	177
%		21·1		17·3		25·6		21·4
May	634	83	615	72	149	20	1,398	175
%		13·1		11·7		13·4		12·5
June	474	47	436	51	31	6	941	104
%		9·9		11·7		19·4		11·1
July	404	82	308	39	48	5	760	126
%		20·3		12·7		10·4		16·6
August	739	123	427	97	113	13	1,279	233
%		16·6		22·7		11·5		18·2
September	389	114	200	30	253	60	842	204
%		29·3		15·0		23·7		24·2
October	573	79	393	67	130	26	1,076	172
%		13·8		18·0		20·0		16·0
November	698	99	571	114	346	74	1,615	287
%		14·2		20·0		21·4		17·8
December	317	90	266	44	824	205	1,407	339
%		28·4		16·5		24·9		24·1
Totals	5,920	986	4,704	796	2,294	493	12,918	2,275
%		16·7		16·9		21·5		17·6

caught fish, which were brought ashore to the laboratory, nearly all the cod were examined at sea during the handling of the research vessel catches. The numbers examined from the various statistical rectangles of the North Sea and on West of Scotland grounds are given in Figure 1, in which the numbers in each of the two size-groups are indicated separately, as well as the numbers of those of unknown length. From the larger numbers in the smaller size-group it is possible to detect those grounds which serve as nursery grounds for immature or adolescent fish.

Figure 1 also shows, by heavy boundary lines, the delineation of the various localities or regions identified later in considering the food analysis. These have been based on a number of considerations including their

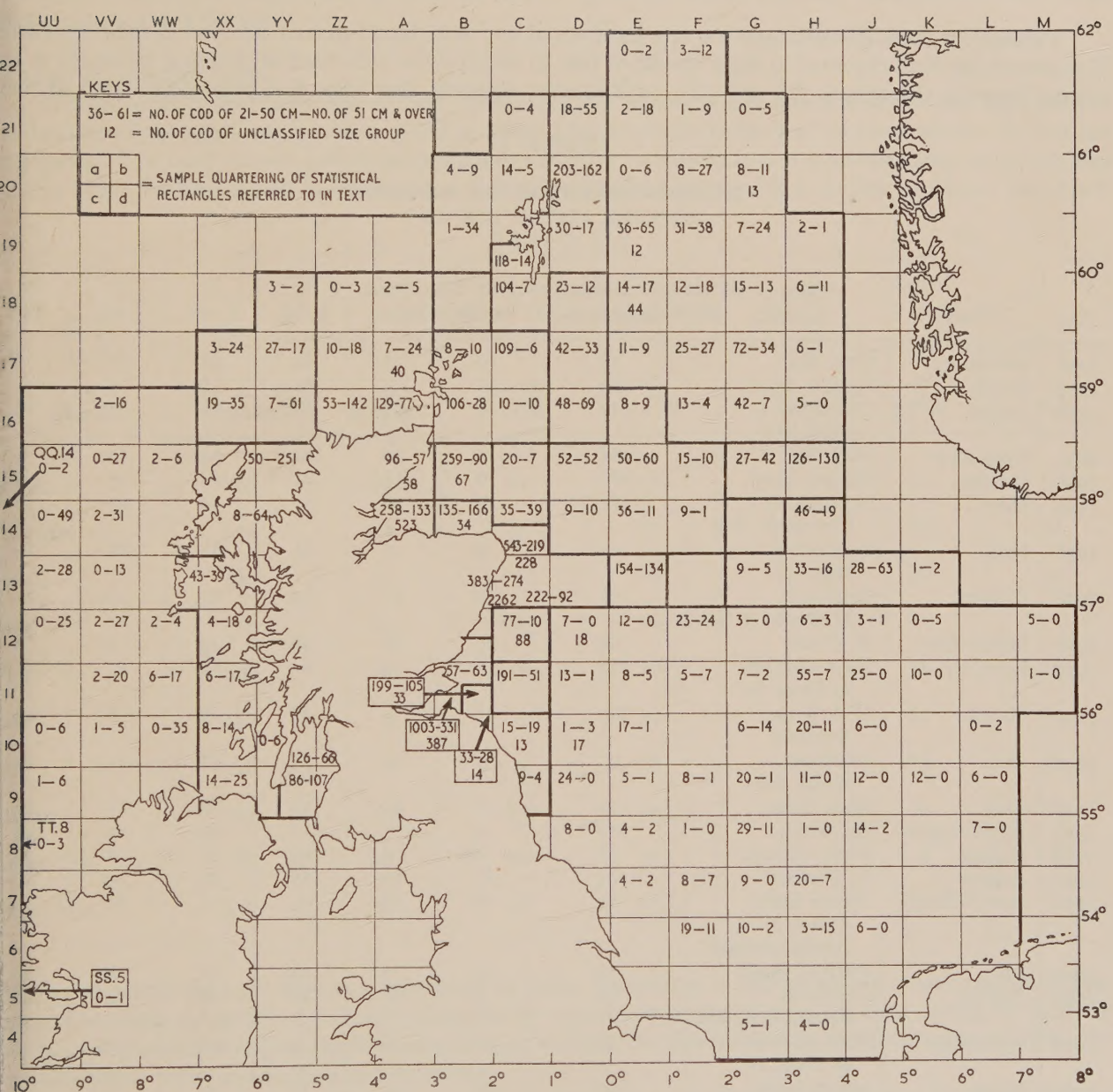

Fig. 1. The sampling of cod stomachs, 1922–1965.

geographical situation, their average depth, the general nature of their ecological conditions and the extent o the sampling of their cod stocks.

VARIATIONS IN FEEDING

Throughout these investigations varying numbers of cod were found to have no food in their stomachs This feature has been observed in other species of fish, in which it has been used in studying variations in th feeding intensity throughout the year. It is well known, however, that some fish regurgitate their stomach

TABLE II

ESTIMATED FULLNESS OF COD STOMACHS, NOVEMBER 1956 TO JUNE 1961

Year	Month	Area or Locality	No. Stomachs examined	% empty	% traces	% ¼ full	% ½ full	% ¾ full	% full
1956	November	N.N. Sea	32	19	13	34	22	9	3
1957	March	Firth of Forth	156	10	3	34	35	7	11
1957	August	Central & N.N. Sea	219	16	25	22	16	7	14
1957	November	N.N. Sea	182	25	14	22	22	14	3
1958	January	Buchan Deep	162	19	23	21	14	15	8
1958	May	Northern & Central N. Sea	177	12	19	21	24	13	11
1958	June	E. Scottish Bight	91	3	2	35	28	22	10
1958	August	Central & N.W. North Sea	53	19	17	13	17	13	21
1958	Sept.—Oct.	N. Coast	64	20	16	40	19	3	2
1959	February	Firth of Forth to Farne Is.	174	8	15	21	18	17	21
1959	March	N. & W. of Scotland	225	25	4	27	22	8	14
1959	May	Southern North Sea	97	9	—	18	31	27	15
1959	May	West Coast	129	7	20	12	22	17	22
1959	July—August	N. Minch	71	4	—	11	23	17	45
1959	August	Firth of Forth	35	6	6	23	34	8	23
1959	August	E. Shetland	144	20	10	28	26	4	12
1959	Nov.—Dec.	Moray Firth, Minch & Aberdeen coast	63	17	18	25	14	10	16
1960	July	Firth of Forth	77	14	8	24	18	9	27
1960	August	Central & Southern N. Sea	98	8	10	28	28	4	22
1960	November	Firth of Forth & Farne Is.	35	6	14	37	26	11	6
1961	March	Moray Firth	66	33	13	23	14	9	8
1961	March	N. & W. Coast	140	14	19	17	19	16	15
1961	June	Moray Firth	36	3	5	25	17	17	33

contents on being caught in a trawl or on a hook. This is particularly noticeable in deep-water species such a ling (*Molva molva*), tusk (*Brosme brosme*) and redfish (*Sebastes* spp.) and to a slight extent is also characteristic c cod. It is possible too that loss of stomach contents occasionally results from the rough treatment the fis sometimes experience in the codend of trawls or seines; the earlier they are caught the greater is the possibilit

f regurgitation. There are no grounds, however, for concluding that the numbers of empty stomachs in cod rom these causes are in any way excessive or that they vary appreciably from one month to another or from one ocality to another. Consequently it seems permissible to regard the numbers of empty stomachs in cod as an ndex of seasonal feeding variations. It has been decided, however, to consider only records obtained by means f the otter trawl and to ignore, for this particular purpose, cod caught by handline or ripper, as there is evidence nat some of the fish so caught tend to throw up some or all of the contents of their stomachs, probably in an ttempt to get rid of the hook.

EASONAL VARIATIONS

The numbers of cod examined in each month and the numbers containing no food (also expressed as ercentages of the totals) are therefore given in Table I for each size-group and for those whose size was not etermined. The final column, giving the percentages of empty stomachs in fish of all sizes combined, indicates fairly active feeding of cod in January and February, followed by a marked decline in March and April.

TABLE III

ESTIMATED FULLNESS OF COD STOMACHS
SUMMARY OF TABLE II BY MONTHS

Month	No. of Cod Examined	% Empty	% with Traces	% ¼ Full	% ½ Full	% ¾ Full	% Full
anuary	162	19	23	21	14	15	8
ebruary	174	8	15	21	18	17	21
Iarch	587	19	8	26	24	10	13
pril	—	—	—	—	—	—	—
Iay	403	10	15	17	25	18	15
ne	127	3	3	32	24	21	17
ly	148	9	4	18	20	13	36
ugust	549	15	17	24	22	6	16
pt.—Oct.	64	20	16	40	19	3	2
ov.—Dec.	312	22	15	25	21	12	5

eeding increases through May to a maximum in June. Thereafter, a decline sets in which continues into eptember, when the numbers of empty stomachs are apparently greater than at any time during the year. In ctober and November an increase in feeding is again evident, but this is followed by another slump in Decem-er comparable with the situation in September.

A study of the proportions of empty stomachs in each of the two size-groups suggests, however, that the tensity of feeding also varies in both the smaller and larger fish from month to month. Moreover, the pro-rtions of non-feeding fish in each size-group may differ appreciably from the corresponding proportions for i sizes. The spawning time for cod in Scottish waters is February-April. It is generally accepted that many fish o not feed while spawning, so that an increase in the proportions of empty stomachs in adult cod in these onths is conceivable. At the same time, however, there is no obvious reason why immature and adolescent d of 21 to 50 cm should also include a relatively high proportion of fish with empty stomachs, as they do in arch and April.

TABLE IV

DIURNAL FEEDING OF COD THROUGHOUT THE YEAR

		00—06 hr			06—12 hr			12—18 hr			18—24 hr		
		No. Ex.	Empty	%	No. Ex.	Empty	%	No. Ex.	Empty	%	No. Ex.	Empty	%
January	1953	30	6		27	11		126	31		13	0	
„	1955	—	—		133	4		95	4		—	—	
„	1958	—	—		112	20		45	8		6	2	
	Total	30	6	20	272	35	13	266	43	16	19	2	11
February	1953	2	0		31	2		22	3		4	1	
„	1955	—	—		52	9		78	12		11	1	
„	1956	—	—		38	16		2	1		25	3	
„	1957	—	—		—	—		—	—		30	7	
„	1959	—	—		28	2		254	16		—	—	
	Total	2	0	0	149	29	19	356	32	9	70	12	17
March	1955	4	0		8	1		2	2		4	0	
„	1956	1	1		8	2		7	1		7	2	
„	1957	10	2		50	8		72	8		31	9	
„	1958	—	—		100	10		85	5		—	—	
„	1959	31	16		70	21		104	17		19	2	
	Total	46	19	41	236	42	18	270	33	12	61	13	21
April	1953	—	—		15	1		5	0		—	—	
„	1955	2	0		19	3		12	2		—	—	
„	1956	27	11		73	8		48	17		9	3	
	Total	29	11	38	107	12	11	65	19	29	9	3	33
May	1953	8	3		257	34		201	22		—	—	
„	1957	3	0		2	0		17	0		1	0	
„	1958	20	0		104	9		71	12		17	2	
„	1959	11	1		43	1		42	5		6	2	
„	1960	—	—		54	5		76	12		—	—	
	Total	42	4	10	460	49	11	407	51	13	24	4	17
June	1956	—	—		37	4		49	1		—	—	
„	1957	16	2		21	7		40	9		64	18	
„	1958	—	—		82	6		41	1		8	0	
„	1959	8	0		85	5		54	6		71	4	
„	1960	—	—		16	2		28	2		24	5	
	Total	24	2	8	241	24	10	212	19	9	167	27	16
July	1955	49	9		31	4		21	4		23	1	
„	1956	27	7		107	29		66	12		117	18	
„	1957	—	—		94	26		31	8		—	—	
„	1959	2	0		39	2		11	0		—	—	
„	1960	29	6		154	22		71	14		1	0	
	Total	107	22	21	425	83	20	200	38	19	141	19	14

TABLE IV (*contd.*)

DIURNAL FEEDING OF COD THROUGHOUT THE YEAR

		00—06 hr			06—12 hr			12—18 hr			18—24 hr		
		No. Ex.	Empty	%	No. Ex.	Empty	%	No. Ex.	Empty	%	No. Ex.	Empty	%
August	1956	4	3		17	3		30	9		2	2	
„	1957	96	18		69	8		41	6		32	5	
„	1958	47	10		46	6		18	4		32	4	
„	1959	—	—		41	3		13	0		23	3	
„	1960	25	3		124	22		36	8		5	1	
	Total	172	34	20	297	42	14	138	27	20	94	15	16
September	1955	10	0		28	2		15	4		5	1	
„	1958	34	8		38	7		1	0		8	0	
„	1959	—	—		96	13		53	16		—	—	
	Total	44	8	18	162	22	14	69	20	29	13	1	8
October	1953	—	—		163	15		83	14		—	—	
„	1959	—	—		31	5		53	7		13	2	
	Total	—	—	—	194	20	10	136	21	15	13	2	15
November	1955	48	13		3	0		9	0		—	—	
„	1956	—	—		70	8		94	10		26	1	
„	1957	25	11		38	7		68	13		71	22	
„	1958	15	3		100	14		89	15		63	21	
„	1959	15	0		27	3		26	8		5	0	
„	1960	—	—		42	8		71	8		9	1	
	Total	103	27	26	280	40	14	357	54	15	174	45	26
December	1955	—	—		30	18		13	0		—	—	
„	1959	—	—		73	6		30	1		—	—	
	Total	—	—		103	24	24	43	1	2	—	—	
Grand Totals		599	133	22	2,926	422	14	2,519	358	14	785	143	18

In the first six months of the year the proportions of empty stomachs in the fish of the two size-groups fluctuate more or less in unison. From July to December, however, empty stomachs in the smaller fish are relatively more numerous in July, September and December, while in the larger fish this feature is evident in August, October and November. While the proportions of empty stomachs in cod of all sizes vary from 11.1 % in June to 24·2 % in September, the proportions within the two size-groups reveal certain inconsistencies for which there are no obvious explanations; and if one considers the similarity of the over-all percentages of 16·7 % for fish of over 21 to 50 cm and 16·9 % for those of 51 cm and over, there is some reason for concluding that the monthly fluctuations in the proportions of empty stomachs may, to some extent, be the result of imperfect sampling.

In the absence of data on the volumes of food in the stomachs, the quantities of food were estimated over a number of years on the basis of the capacity of the stomachs. The results are given in Table II, in which the numbers of stomachs in each category of fullness are expressed as percentages of the numbers examined.

This shows, rather more clearly than Table I, that on the whole the proportions of fish with empty stomachs are low during the summer months and relatively high during the winter and spring. At the same

time the numbers of fish with full stomachs are highest during the summer and lowest during the winter and spring. This is demonstrated even more clearly in Table III, in which the records in Table II have been condensed.

From these investigations it may be concluded that cod feed fairly intensively throughout the entire year. Feeding increases during January and February—in February, rather surprisingly, the amount of food in the stomachs is comparable with the quantity eaten during the summer. Feeding falls off in March and evidently also in April. This could result from a decline in feeding while spawning is in progress, although relatively few spawning fish were examined over the period of these studies and, as will be shown later, no conclusive evidence was found to support the view that feeding ceases entirely at spawning time. Furthermore the apparent increase in the numbers of empty stomachs in fish of 21 to 50 cm (Table I) during the same months is somewhat disconcerting, since few, if any, of this size-group could possibly be at the spawning stage.

From May onwards, however, the intensity of feeding increases to a maximum in July, when more than a third of the fish of all sizes were gorged with food and nearly 70 % of the stomachs were half full or more. During these months the numbers of empty stomachs were at their lowest. From August to the end of the

TABLE V

INTENSITY OF FEEDING OF COD DIURNALLY
SCOTTISH WATERS—NOVEMBER 1956 TO AUGUST 1959

	00—06 hr	%	06—12 hr	%	12—18 hr	%	18—24 hr	%
No. empty	42	23	97	12	99	15	18	11
No. with traces	30	17	111	14	66	10	26	16
No. ¼ full	42	23	185	23	173	25	36	22
No. ½ full	26	14	178	22	167	24	43	27
No. ¾ full	14	8	107	13	82	12	18	11
No. full	27	15	128	16	94	14	20	13
Totals	181		806		681		161	

year the numbers of full or nearly full stomachs decline while the numbers of empty or nearly empty stomachs increase. The feeding cycle of cod in Scottish waters would, therefore, appear to start with a relatively short but sharp rise in January and February, which is followed by a decline over March and April which may or may not be associated with a falling off in feeding during the spawning period. The intensity of feeding then increases in May, June and July, which must be regarded as the principal feeding period. Although the majority of cod continue to feed over the remainder of the year, the quantities of food consumed decline steadily from August to December.

Diurnal Variations

The increase in research in fish behaviour among other things has stimulated an interest in their diurnal feeding habits. In order to study this feature in cod the numbers and proportions of empty stomachs found in each quarter of the 24 hours are set out in Table IV. The records include only those months and years in which sufficiently large numbers of fish were examined to provide representative samples in one or more of the four

periods of six hours. The times of hauls throughout the year have been adjusted so that all records conform to Greenwich mean time. The records for individual months reveal some remarkable variations in the proportions of empty stomachs within the four quarters. The monthly totals for all the years combined again reflect the seasonal differences already observed in Tables I–III. In addition, however, they also show that the proportion of empty stomachs tends to be rather higher from midnight to 0600 hours than in any of the other three quarters.

This suggests that cod feed rather less heavily in the first quarter of the day than at other times. This is perhaps most clearly demonstrated by the grand totals at the bottom of Table IV (22 % of the stomachs empty), which also suggest that feeding is heaviest during the two daylight quarters from 0600 to 1800 hours (14 % empty) and falls off from 1800 to 2400 hours (18 % empty).

These observations are based entirely on the presence or absence of food and do not take into account the quantities present in the stomachs. From November 1956 to August 1959 the observations recorded also included estimations of the fullness of the stomachs. These have been summarised in Table V, and this again shows a higher proportion of empty stomachs from midnight to 0600 hours, but it also shows that the proportion of full stomachs during these hours (15 %) is comparable with the proportions in the other three quarters

TABLE VI

FOOD OF SMALL CODLING (11—20 CM) IN FIRTH OF FORTH

JANUARY TO MARCH, 1955 TO 1959

No. of stomachs examined	65		
No. empty	1		
No. with recognisable food	64		
Percentage containing:			
CRUSTACEA	91	PISCES	16
Decapoda ? spp	6	*Ammodytes*	2
Eupaguridae	3	*Hippoglossoides*	2
Portunus	2	*Clupea harengus*	2
Crangon	59	*Gobius minutus*	8
Pandalus	14	POLYCHAETA	8
Euphausiacea	2		

NOTE—In this table and in those which follow the frequency of occurrence of each food type in the stomachs is expressed as a percentage of the number containing recognisable food.

of the day. The observations would seem to show that cod may feed at any time throughout the twenty-four hours. Undoubtedly some fish feed heavily at certain times of the day (for example a large body of cod in the Firth of Forth was found to be gorged with fresh food from 0900 to 1200 hours in January 1955) but this is by no means characteristic of this species, and the evidence of the quantities and the nature of the food in the stomachs suggests considerable variation in feeding habits, both in time and place. It would appear that, in general, feeding is rather less heavy during the hours of darkness, especially from midnight to 0600 hours and to a somewhat less extent from 1800 to 2400 hours. At the same time it must be borne in mind that some of the food eaten by fish caught in any quarter could have been ingested in the previous 6 hours' period or even earlier. For example, it has been shown by Tarverdieva (1963) and by Mr R. Jones of the Marine Laboratory, Aberdeen (results unpublished) that under experimental conditions fish, including cod, may retain some of the food from a meal for anything up to several days, depending on the temperature of the water and probably also on other factors. Whether this is also characteristic of the cod under natural conditions, however, remains to be demonstrated. At the same time, it is possible that the greater quantities of food observed in the stomachs during daylight, 0600 to 1800 hours, reflects, to some extent, dawn and dusk feeding habits as already indicated by Graham (1924) and by later investigators.

TABLE VII

FOOD OF SMALLER COD IN FIRTH OF FORTH, 1950—1961

Length range cm	21–50	21–50	21–50	21–50	21–50	21–50	21–50
Months	I, II	III	IV, V, VI	VII, VIII	IX, X	XI, XII	I–XII
No. of stomachs examined	131	264	158	139	109	202	1,003
No. empty	14	34	38	25	15	14	140
No. with recognisable food	117	230	120	114	94	188	863
Percentage containing:							
CRUSTACEA	92	83	81	64	91	95	85
Decapoda ? spp	12	1	—	—	—	2	2
Eupaguridae	8	1	3	1	16	1	4
Portunus	13	8	8	15	17	11	11
Hyas	1	1	1	—	—	—	1
Atelecyclus	1	—	1	1	—	1	+
Corystes	—	—	1	—	—	—	+
Pinnotheres	2	—	—	—	—	—	+
Nephrops	8	20	18	12	4	18	15
Galathea	1	1	—	—	1	5	2
Munida	1	1	2	—	6	—	1
Crangon	40	47	11	11	35	55	37
Pandalus	38	28	33	3	18	18	24
Hippolyte	1	—	—	—	—	—	+
Nika	2	—	—	—	—	—	+
Isopoda	—	—	—	1	—	—	+
PISCES	38	34	40	43	17	17	31
Ammodytes	3	3	3	11	—	2	3
Gadus sp.	4	—	1	—	—	1	1
G. merlangus	3	3	—	—	—	1	1
G. esmarkii	1	—	—	—	—	—	+
Flatfish sp.	1	+	—	—	—	—	+
Limanda	1	—	1	—	—	—	+
Hippoglossoides	2	1	2	—	2	2	1
Clupea sp.	5	—	—	1	—	—	1
C. harengus	—	4	5	—	1	—	2
C. sprattus	3	—	—	—	—	—	+
Lumpenus	7	10	15	10	—	5	8
Gobius minutus	1	3	—	—	2	1	1
Agonus	1	—	1	—	—	1	+
Trigla gurnardus	1	—	—	—	—	—	+
Callionymus lyra	—	—	—	1	—	—	+
Pholis gunnellus	—	+	1	—	—	—	+
Cottus sp. incl. spawn	1	+	—	—	—	—	+
MOLLUSCA	—	—	3	—	2	1	1
Cephalopoda	—	—	1	—	—	—	+
POLYCHAETA	11	7	2	4	4	4	5
Aphrodite	3	2	—	2	1	1	1
Arenicola	—	—	—	—	2	1	+
Nereidae	—	—	—	—	—	1	+
GEPHYREA	2	—	—	—	—	1	+
OPHIUROIDEA	—	—	2	—	—	—	+

TABLE VIII

FOOD OF LARGER COD IN FIRTH OF FORTH, 1950—1961

ength range cm	51–90	51–79	51–79	51–106	51–92	51–106
lonths	I, II	III	IV, V, VI	IX, X	XI, XII	I–XII
o. of stomachs examined	79	47	76	31	98	331
o. empty	1	—	14	6	4	25
o. with recognisable food	78	47	62	25	94	306
ercentage containing:						
CRUSTACEA	77	87	84	84	83	82
Decapoda ? spp	5	—	—	8	2	3
Eupaguridae	3	—	—	—	3	2
Portunus	27	4	31	24	34	26
Atelecyclus	—	—	2	—	—	+
Corystes	—	—	—	—	1	+
Nephrops	21	64	53	40	28	38
Galathea	1	—	—	—	—	+
Munida	—	—	3	—	1	1
Crangon	36	36	3	16	22	23
Pandalus	47	26	11	8	16	24
Hippolyte	—	—	—	—	2	1
PISCES	82	43	47	24	52	55
Ammodytes	8	—	2	—	1	3
Gadus sp.	5	—	—	—	4	3
G. aeglefinus	—	—	—	4	—	+
G. merlangus	10	2	2	—	4	5
G. esmarkii	1	—	—	—	—	+
G. callarias	1	—	—	—	—	+
Flatfish sp.	4	2	—	—	—	1
Limanda	3	2	—	4	1	2
Microstomus	—	—	—	4	—	+
Hippoglossoides	6	9	3	4	11	7
Clupea sp.	23	—	—	—	—	6
C. harengus	10	9	5	—	5	7
C. sprattus	29	—	—	—	2	8
Lumpenus	5	17	21	—	5	10
Gobius minutus	8	—	—	—	2	3
Agonus cataphractus	5	—	2	—	—	2
Callionymus lyra	4	—	—	—	—	1
Onos cimbrius	1	—	—	—	—	+
Cottus sp. inc. spawn	—	—	—	—	1	+
MOLLUSCA	1	—	—	—	3	1
Gasteropoda	—	—	—	—	2	1
Cephalopoda	1	—	—	—	—	+
POLYCHAETA	8	9	2	4	2	5
Aphrodite	4	6	2	—	2	3
Nephthys	1	—	—	—	—	+
Phyllodocidae	—	—	—	4	—	+
OPHIUROIDEA	—	2	—	—	—	+
HYDROIDA	1	—	—	—	—	+
CTENOPHORA (*Beröe*)	1	2	—	—	—	1

ANALYSIS OF COD FOOD

Most of the cod handled in this investigation of the food were examined during the routine treatment of the research vessel catches immediately following the hauling of the trawl. The contents of the stomachs were thus identified in as fresh a state as possible, although naturally much of the food was in various stages of digestion. Partly as the result of this practice and partly because the food of cod of 21 cm and over consists very largely of organisms of an appreciable size with readily recognisable features such as claws, bones and otoliths, the identification of the main food types presented little difficulty. Consequently only negligible proportions of the stomach contents were not identifiable.

The purpose of this work from its inception in the years following the first World War was to obtain a general impression of the composition of the food. To achieve this the prime object was to identify the principal groups preyed upon and to run the various organisms down as far as possible to the genus or species. In general little effort was made to identify the individual species eaten, but where these were easily recognised, the observations were recorded. In the Tables which follow, the food items are listed mainly under their generic names unless it is desirable to distinguish different species of the same genus. A list of the genera and species identified, with their place of occurrence, is given in the Appendix. The records are considered on a local or regional basis.

Firth of Forth

In these studies the Firth of Forth is regarded as the area east of Inchkeith and west of the line joining Fife Ness, the Isle of May and the Bass Rock. The depth of the water at no point exceeds 30 fathoms and the bottom consists variably of sand and mud. The cod samples have on the whole been obtained from the deeper parts in which mud predominates. During the period 1950 to 1961, 1003 codling of 21–50 cm and 331 of 51 cm and over were examined. Not all the small codling in the catches were examined, however, so that these figures do not represent the true proportions of the fish in the two size-groups, and of those of 51 cm and over, the majority were fish of 51–65 cm, and cod of 75 cm and over were remarkably scarce. The Firth of Forth must, therefore, be regarded primarily as a nursery ground for immature and adolescent cod.

Although these investigations have been concerned almost entirely with the food of cod of 21 cm and over, 65 fish of 11–20 cm have been examined (Table VI). These do little more than indicate the importance of crustaceans in their diet, in which small *Crangon* is the commonest sub-type.

The analysis of the food of cod of 21–50 cm and of 51 cm and over (Tables VII and VIII) reveals the overall importance of decapod crustaceans, particularly the natant types, and fish to cod of both size-groups. The polychaete worm *Aphrodite* was also eaten regularly throughout the year by fish of all sizes, but molluscs, gephyreans, ophiuroids, hydroids and ctenophores were eaten only on rare occasions. In view of the frequency with which ctenophores and other planktonic types are eaten by cod in Arctic seas, it is of interest to draw attention to the two records of *Beroe* found in cod stomachs, the first west of the Isle of May in March 1950 and the second to the south of the same island in January 1955; four *Beroe* had been eaten by one fish on the latter occasion. There is an earlier record of a ctenophore in the stomach of a cod from the same area, in October 1890 (Smith, 1891). Tables VII and VIII show that the food of the two size-groups is remarkably similar as regards the types of animals eaten. They also show that cod in the smaller size-group, 21–50 cm, prey more heavily on crustaceans than on fish and that the larger cod, 51 cm and over, although still feeding predominantly on crustaceans, nevertheless eat more fish than the smaller cod.

Four types of decapod crustaceans are outstanding in the diet of the fish in each size-group. These are *Crangon* and *Pandalus*, which are eaten more frequently by the smaller cod, and *Portunus* and *Nephrops*, which figure more prominently in the diet of the larger fish. With the exception of hermit crabs (*Eupaguridae*), which are taken fairly regularly by the smaller fish, none of the other decapod types is found in more than one or two per cent of the stomachs.

At least 18 species of fish were identified in the stomachs, and of these an estuarine form, *Lumpenus lampetraeformis*, proved to be the commonest single species preyed upon (8 % of the smaller fish, 10 % of the larger fish). Collectively the clupeoids were the most important group (3 % and 21 %), with flatfishes (2 % and 10 %) and small gadoids, mainly whiting (2 % and 8 %), next in importance.

TABLE IX

PERCENTAGES OF COD (ALL SIZES) FEEDING ON THE PRINCIPAL FOOD TYPES IN FIRTH OF FORTH, BY MONTHS 1950—1961
(PRINCIPAL FOOD ITEMS IN BOLD TYPE)

	Length range cm	No. stomachs with recognisable food	Percentage of Cod feeding on												
			C	E	Po	N	Cr	Pa	P	A	G	F	Cl	L	Py
March 1950	25–71	94	64	—	11	**26**	7	19	**53**	7	7	3	**9**	7	4
April 1952	32–79	70	81	—	**21**	27	3	**31**	41	—	1	7	**11**	4	—
October 1952	21–75	92	**90**	**16**	14	9	**36**	21	21	—	—	4	1	—	4
April 1953	23–61	20	85	5	10	**25**	10	**50**	**50**	—	—	—	5	**10**	—
January 1955	21–90	117	79	3	**21**	15	**43**	**46**	**75**	**8**	**20**	**9**	**49**	4	7
November 1956	21–73	145	**93**	—	15	**26**	**55**	3	17	2	1	6	1	2	4
March 1957	21–64	171	**95**	2	6	**26**	**68**	**34**	26	1	—	4	2	**13**	**9**
December 1958	21–70	48	**92**	—	**27**	10	**63**	**31**	29	2	—	—	8	—	—
February 1959	21–63	78	**95**	**9**	14	10	**32**	**35**	26	—	1	4	3	**9**	**14**
August 1959	22–55	24	79	—	13	17	13	4	29	—	—	—	—	—	—
December 1959	28–92	42	76	7	19	**31**	**36**	29	**62**	—	**14**	7	5	**24**	5
April 1960	21–92	36	83	—	19	**47**	8	17	47	—	—	—	—	**39**	3
May 1960	36–75	13	**100**	—	8	**31**	8	23	31	—	**8**	—	—	**23**	—
June 1960	24–60	22	64	—	9	**36**	5	9	**59**	**14**	—	—	—	**36**	**9**
July 1960	19–54	52	58	2	4	15	15	—	**56**	**23**	—	—	2	**13**	4
August 1960	22–58	38	63	—	**32**	5	5	5	34	—	—	—	—	**11**	5
October 1960	28–71	23	**96**	—	**39**	13	17	—	4	—	—	—	—	—	4
November 1960	25–66	47	**98**	2	**21**	9	—	**38**	36	2	**11**	6	—	2	4
June 1961	21–50	21	86	**10**	5	10	29	14	19	**10**	—	—	—	5	—

KEY — C=Crustacea, E=Eupaguridae, Po=*Portunus*, N=*Nephrops*, Cr=*Crangon*, Pa=*Pandalus*, P=Pisces, A=*Ammodytes*, G=Gadoids, F=Flatfishes, Cl=Clupeoids, L=*Lumpenus*, Py=Polychaeta

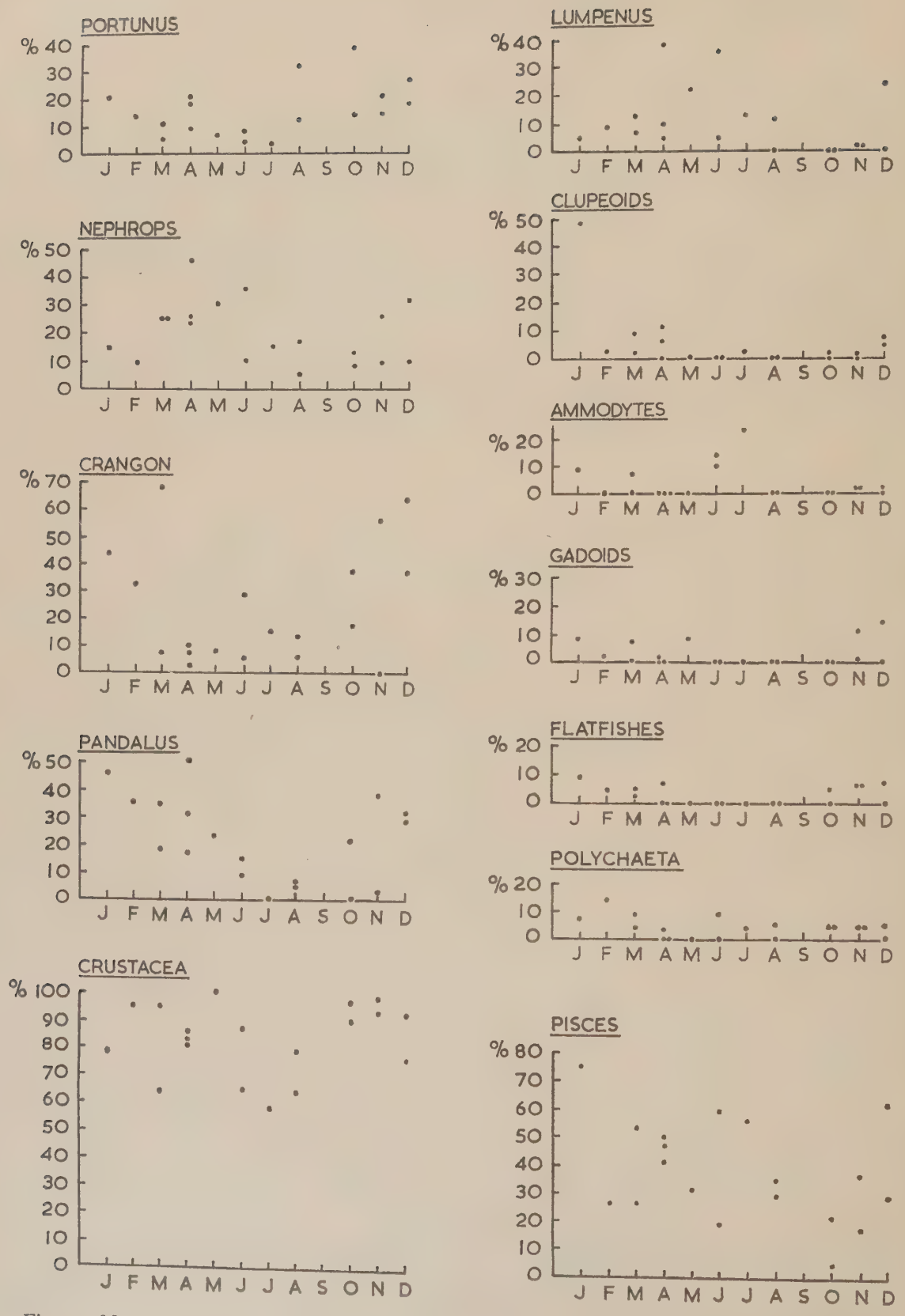

Fig. 2. Monthly variations in the food of cod in the Firth of Forth, 1950–1961, showing percentages of cod of all sizes feeding on the principal food types.

TABLE X

FOOD OF COD IN FIRTH OF FORTH (BIIc), 1922—1925

Length range cm	21–100		
Months	III, IV, VII, IX, XI		
No. stomachs examined	322		
No. empty	66		
No. with recognisable food	256		
Percentage containing:			
CRUSTACEA	82	PISCES	28
Decapoda ? spp.	+	*Ammodytes*	3
Eupaguridae	4	*Gadus aeglefinus*	+
Portunus	24	*G. merlangus*	7
Nephrops	11	*G. callarias*	+
Galathea	3	*Limanda limanda*	3
Munida	2	*Hippoglossoides*	3
Crangon } *Pandalus*	42	*Microstomus kitt*	+
		Clupea harengus	1
MOLLUSCA	1	*Molva molva*	1
Gasteropoda	+	*Lumpenus*	+
Buccinum	+	*Gobius*	+
POLYCHAETA	4	*Pholis gunnellus*	1
Aphrodite	3		
OPHIUROIDEA	1		

TABLE XI

FOOD OF COD IN FIRTH OF FORTH, 1888—1891, FROM W. R. SMITH (1892)
ALL SIZES

No. stomachs examined	721		
No. stomachs with recognisable food	641		
Percentage containing:			
CRUSTACEA	87	PISCES	50
Decapoda ? spp.	3	*Ammodytes*	3
Eupagurus	14	*Gadus aeglefinus*	1
Eupaguridae	8	*G. merlangus*	7
Portunus	22	*G. callarias*	1
Porcellana	1	*Hippoglossoides platessoides*	3
Pinnotheres	+	*Limanda limanda*	1
Spider crabs	1	*Clupea harengus*	3
Hyas	3	*Clupea sprattus*	1
Nephrops	17	*Lumpenus lampetraeformis*	2
Galathea	2	*Gobius* sp.	+
Munida	+	*Agonus cataphractus*	2
Crangon	18	*Trigla gurnardus*	+
Pandalus	12	*Onos* sp.	+
Balanus	+	MOLLUSCA	11
ANNELIDA	6	Gasteropoda	5
Aphrodite sp.	5	*Buccinum* sp.	5
Arenicola sp.	+	*Turritella* sp.	+
ECHINODERMATA	1	*Fusus* sp.	+
Ophiuroidea	1	Lamellibranchiata	4
" Sand Stars "	+	*Pecten* sp.	2
COELENTERATA	+	*Solen* sp.	2
Ctenophore	+	*Scrobicularia* sp.	+
Medusid	+	Cephalopoda	+
		Rossia sp.	+

Seasonal differences in the food

In Tables VII and VIII the records have been grouped on a monthly or seasonal basis in order to demonstrate any possible seasonal variation in the nature of the food. Over the entire period of the investigations there is some evidence of certain types being eaten more, or less, frequently than others at certain times of the year. Crustaceans appear to be taken less frequently during the summer and fish less frequently from September to December by the smaller cod. The larger cod appear to eat fewer crustaceans in January or February, at which time they prey heavily on fish. Throughout the rest of the year the larger cod feed heavily on crustaceans, while their intake of fish remains at a much lower level and falls to a minimum in September.

Tables VII and VIII also suggest that over the years the numbers feeding on individual food types vary from month to month. This is most noticeable in *Crangon* and *Pandalus*, each of which appears to be eaten most frequently in the first quarter of the year and is of least importance to cod during the spring and summer. In order to study this variation in more detail, the percentages of cod of all sizes feeding on the principal food types in each month and year in which sufficiently representative samples were procured are given in Table

TABLE XII

FOOD OF COD IN ST ANDREW'S BAY AND BELL ROCK AREA (B11ab) 1922—1959

Months	III–V, X–XII				
Length Range cm	21–50	51–100			
No. stomachs examined	57	63			
No. empty	9	5			
No. with recognisable food	48	58			
Percentage containing:					
CRUSTACEA	96	47	PISCES	12	86
Decapoda ? spp.	2	—	*Ammodytes*	—	22
Eupaguridae	17	7	*Gadus merlangus*	—	9
Portunus	8	24	Flatfish sp.	—	3
Hyas	12	—	*Pleuronectes platessa*	—	2
Corystes	—	10	*Limanda limanda*	—	12
Nephrops	—	7	*Hippoglossoides*	2	2
Galathea	10	—	*Clupea* sp.	—	5
Munida	6	2	*Clupea harengus*	—	3
Crangon	33	12	*Clupea sprattus*	—	5
Pandalus	35	—	*Callionymus lyra*	2	2
Mysidacea	4	—	*Agonus*	—	10
CEPHALOPODA	—	2	*Gobius* sp.	—	2
Eledone cirrhosa	—	2			
POLYCHAETA, *Aphrodite*	4	2			
OPHIUROIDEA	4	2			

IX and illustrated in Figure 2. These tend to confirm the variations already noted, particularly the decline in the numbers of *Crangon* and *Pandalus* eaten during the late spring and summer, and seem to reveal varying seasonal importance of fish, for example, the increase in the numbers of sand eels eaten in June and July and the lack of gadoids and flatfish from June to October. However, it is also evident that the percentages of cod feeding on each food type vary considerably in nearly every month. This may indicate some preference by the cod, but on the other hand it may reflect a scarcity or abundance of the various types owing to annual fluctuations in their natural recruitment. It is also possible that the percentages may rise or fall according to the distribution of the different food animals and of the cod shoals within the firth. Finally, the stock of young cod in the Forth is also known to vary from year to year, owing to annual fluctuations in the recruitment.

Comparison of food during 1950–1961 *with that of earlier years*

Marked changes have taken place in the commercial fisheries of the Firth of Forth and in the regulations affecting them since the first great war. Prior to that war drift-netting for herring was still carried out in the

firth, and fishing for white fish was by baited hook and line and by flounder seine. Since that time the drift-net fishery for adult herring has disappeared and a fishery for young herring and sprats by ring-net, pelagic trawl and seine net for industrial purposes has arisen. The opening of the firth to Danish seining between the wars and more recently to prawn trawling, has led to a considerable reduction in the stocks of sizeable whitefish (Lamont, 1964).

In view of these changes it is of interest to compare the food of cod from 1950 to 1961 with that recorded on Scottish research vessels during the years 1922 to 1925 and with that of the period 1888 to 1891 as determined by Smith (1892). These analyses (Tables X and XI) reveal a remarkable similarity in each period to the food during the years 1950 to 1961. *Portunus, Nephrops, Crangon* and *Pandalus* were the crustaceans most commonly eaten in each period with the Eupaguridae coming next in importance. Fish again appear to have been eaten less frequently than crustaceans but much more frequently than molluscs and other group types, and, as in the years 1950 to 1961, they were represented by a fairly large number of individual species among which the

TABLE XIII

FOOD OF COD FROM ISLE OF MAY TO FARNE ISLANDS (B11d, B10, C10, C9) 1952—1961

Months	January–December						
Length range cm	11–20	21–50	51–101				
No. stomachs examined	60	256	156				
No. empty	5	29	14				
No. with recognisable food	55	226	142				
Percentage feeding on:							
CRUSTACEA	85	67	82	PISCES	9	54	55
Decapoda ? spp.	11	2	3	*Ammodytes*	5	18	10
Eupaguridae	—	4	8	*Gadus* sp.	—	2	4
Portunus	2	12	18	*G. merlangus*	—	1	1
Hyas	—	3	1	Flatfish sp.	—	3	3
Atelecyclus	—	1	6	*Hippoglossoides*	—	3	7
Corystes	—	+	1	*Clupea harengus*	—	—	1
Ebalia	—	+	—	*C. sprattus*	—	1	1
Nephrops	—	12	39	*Onos cimbrius*	—	—	1
Galathea	4	6	1	*Callionymus lyra*	—	1	1
Crangon	25	19	20	*Lumpenus*	—	19	27
Pandalus	7	22	15	*Merluccius*	—	—	1
Hippolyte	—	—	1	*Liparis*	—	+	—
Euphausiacea	9	1	1	*Raia radiata*	—	—	1
Amphipoda	2	—	—	POLYCHAETA	13	3	11
MOLLUSCA	2	2	1	*Aphrodite*	—	2	7
Gasteropoda	2	—	—	*Phyllodoce*	—	—	1
Lamellibranchiata	—	1	—	GEPHYREA	—	—	1
Cephalopoda	—	1	1	ANTHOZOA	—	—	1
OPHIUROIDEA	—	+	—	CTENOPHORA (*Beröe*)	—	—	1

whiting appears to have been the most frequent constituent of the food. Such differences as occur in the three periods are negligible so that, despite the changes in the stocks of commercially important fish within the Firth of Forth, no significant change appears to have taken place in the food of cod in the course of nearly 80 years.

THE EAST SCOTTISH BIGHT

For the purposes of this investigation the East Scottish Bight has been divided into three areas, St Andrews Bay and the Bell Rock, coastal grounds from the Isle of May to the Farne Islands, and the offshore rectangles C11 and C12.

St Andrews Bay and the Bell Rock area (Table XII)

This small area is characterised by shallow depths and a predominantly sandy bottom. The western shallower half is an important nursery ground for flatfishes but small codling are also present; the eastern half

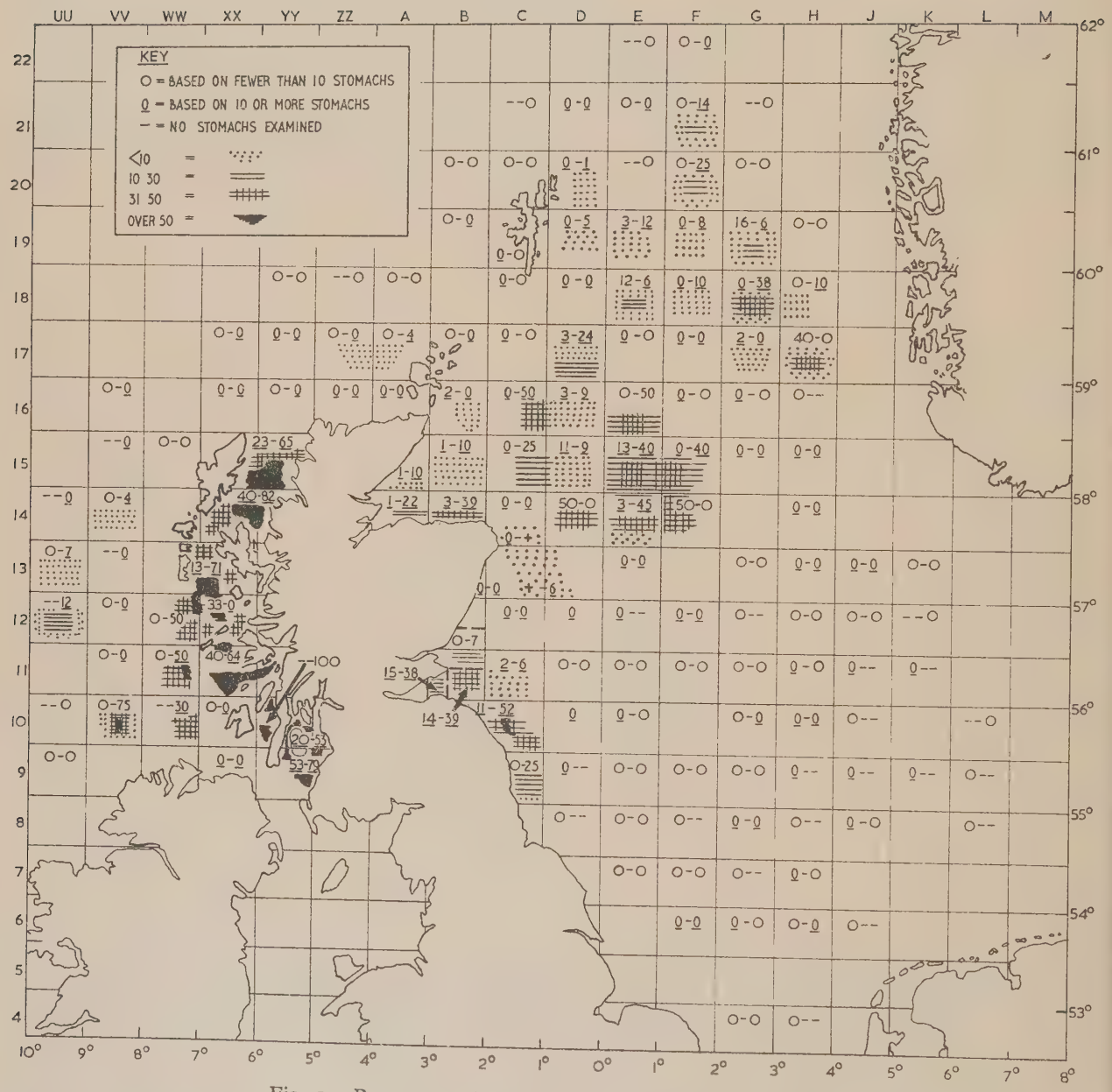
KEY
O = BASED ON FEWER THAN 10 STOMACHS
0 = BASED ON 10 OR MORE STOMACHS
– = NO STOMACHS EXAMINED
<10 =
10 30 =
31 50 =
OVER 50 =
UU VV WW XX YY ZZ A B C D E F G H J K L M
22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4
62° 61° 60° 59° 58° 57° 56° 55° 54° 53°
10° 9° 8° 7° 6° 5° 4° 3° 2° 1° 0° 1° 2° 3° 4° 5° 6° 7° 8°

Fig. 3. Percentage of cod feeding on *Nephrops norvegicus*.

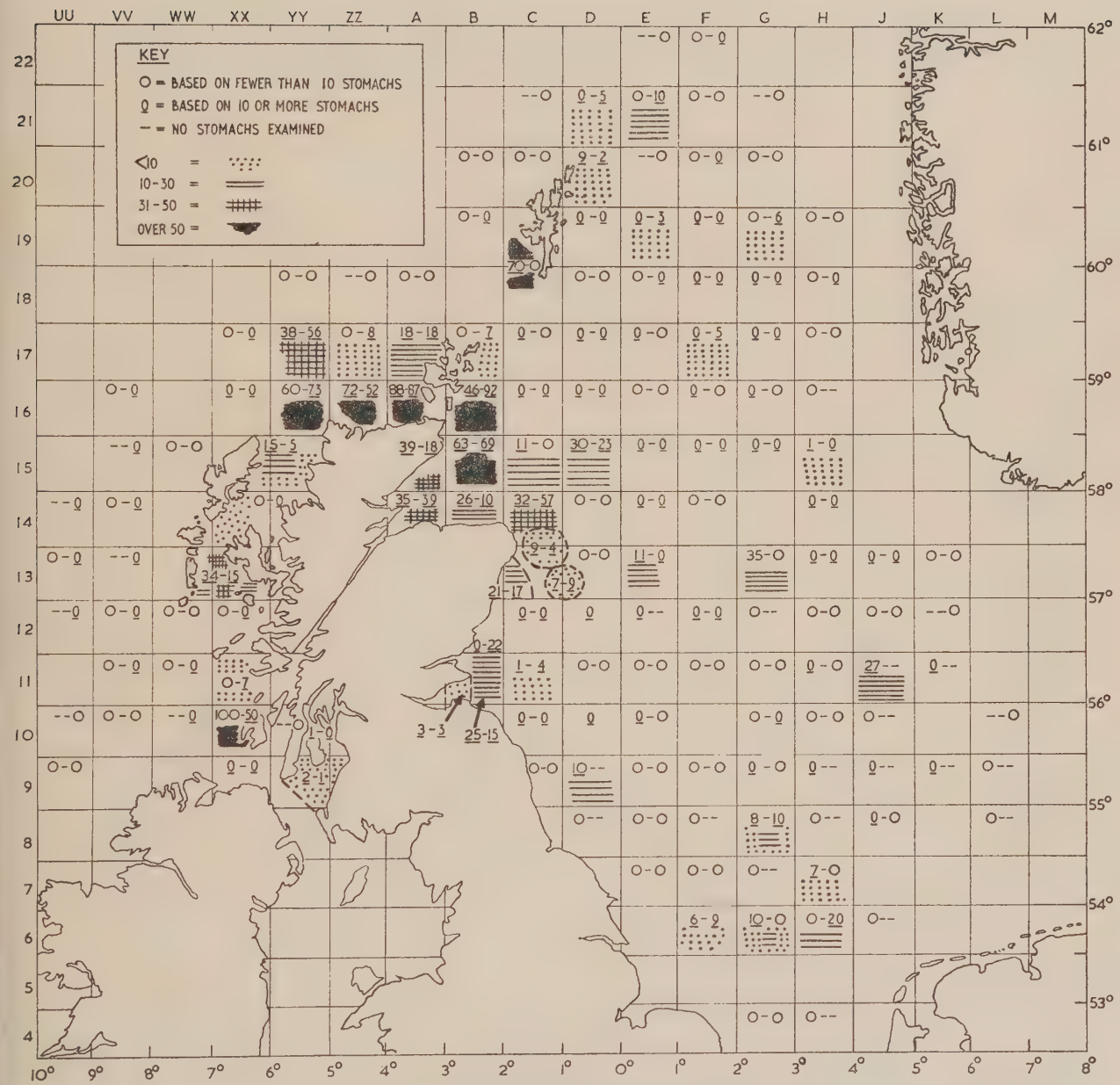
KEY
O = BASED ON FEWER THAN 10 STOMACHS
0 = BASED ON 10 OR MORE STOMACHS
– = NO STOMACHS EXAMINED
<10 =
10-30 =
31-50 =
OVER 50 =
UU VV WW XX YY ZZ A B C D E F G H J K L M
22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4
62° 61° 60° 59° 58° 57° 56° 55° 54° 53°
10° 9° 8° 7° 6° 5° 4° 3° 2° 1° 0° 1° 2° 3° 4° 5° 6° 7° 8°

Fig. 4. Percentage of cod feeding on *Ammodytes* spp.

is a spawning place for cod. Although sampling has not been so extensive as in the Firth of Forth, the results show a preponderance of decapod crustaceans in the food of the smaller cod, with *Crangon* and *Pandalus* outstanding. Eupagurids, *Hyas* and *Galathea* are also prominent but *Portunus* is less so and *Nephrops* apparently was not eaten by the smaller fish.

The food of the larger cod in this area consisted principally of fish, sand eels appearing in 22 %, flatfishes in 20 % and small clupeoids in 13 % of the stomachs. Common dabs and *Agonus cataphractus* were the commonest individual species eaten. In sharp contrast to the food of the smaller fish, *Portunus*, *Crangon* and *Corystes* were the commonest decapods eaten. It is also interesting to note the decline in the occurrence of crangonids and pandalids and the reappearance of *Nephrops* in the stomachs of the larger fish.

TABLE XIV

FOOD OF COD IN EAST SCOTTISH BIGHT (C11, C12)

Area	CII		C12
Years	1924–1958		1922–1954
Months	I, IV, V, VI, X		I, IV, V, VI, VII, IX, X, XII
Length range cm	21–50	51–100	21–98
No. stomachs examined	191	51	175
No. empty	12	2	49
No. with recognisable food	179	49	126
Percentage containing:			
CRUSTACEA	86	78	84
Decapoda ? spp.	3	2	—
Eupaguridae	22	37	29
Portunus	18	27	4
Hyas	4	8	9
Carcinus	—	—	1
Corystes	1	14	—
Nephrops	2	6	—
Galathea	6	2	1
Munida	—	—	2
Crangon	1	—	48
Pandalus	20	2	
Euphausiacea	1	—	—
Amphipoda	—	—	1
MOLLUSCA	5	2	6
Lamellibranchiata	1	—	—
Gasteropoda	1	—	2
Cephalopoda	—	2	—
POLYCHAETA	1	2	2
Aphrodite	1	2	2
OPHIUROIDEA	1	2	—
PISCES	30	59	23
Ammodytes	1	4	—
Gadus sp.	5	8	—
G. merlangus	1	—	2
G. esmarkii	2	4	—
G. aeglefinus	—	—	6
Limanda limanda	1	—	1
Hippoglossoides	1	6	—
Clupea harengus	1	2	—
C. sprattus	1	6	—
Scomber scombrus	—	—	2
Onos	1	2	1
Callionymus lyra	—	—	2
C. maculata	5	6	—
Lumpenus	1	—	—
Trigla gurnardus	1	—	—
Agonus	1	—	—
Gobius	—	2	2
Pholis gunnellus	—	—	2
Triglops	—	—	1

The Isle of May to the Farne Islands (*Table XIII*)

The sea bottom in this area varies considerably from fine sand and mud to very rough sand at depths of 20 to 40 fathoms. In general it is a nursery ground for cod, although fish of the larger size-group are rather more numerous than inside the Firth of Forth. As in the firth, sampling extended over the entire year and included a small number of codling in the 11–20 cm size group. The food analyses show the predominance of smaller crustaceans, for example young *Crangon* and euphausiids, and small polychaetes in the diet of the smallest cod. Decapod crustaceans are the chief food of both the 21–50 cm and 51–101 cm size-groups. The commonest subtypes, *Portunus*, *Nephrops*, *Crangon* and *Pandalus*, reveal a remarkable similarity in the frequency of their occurrence to the food within the Firth of Forth. Of the fish types preyed upon, *Lumpenus*, as within the firth, is the outstanding single species, although sand eels are equally prominent in the stomachs of the 21–50 cm size-group. The discovery of a single specimen of the ctenophore *Beroe* in one cod is also worthy of note.

The offshore rectangles, C11 and C12 (Table XIV)

In these rectangles the depths are somewhat similar to those of the last area and the bottom includes extensive areas of rough ground with sand, shells and gravel intervening. The cod stock consists largely of young fish of less than 51 cm. The food of both size-groups consists chiefly of decapod crustaceans. In rectangle C11 eupagurids are the principal sub-type with *Portunus* a close rival. *Pandalus* is prominent in the diet of the small fish and Corystes in that of the larger fish.

In rectangle C12 eupagurids are again the chief food, while *Crangon, Pandalus* and *Hyas* are also eaten fairly frequently. Eighteen different species of fish are listed in Table XIV in which small gadoids occur rather more frequently than any other type.

TABLE XV

FOOD OF COD IN THE SOUTHERN NORTH SEA

Years	1922	1928–35		1938–65	
Months	X	V–XI		I, IV, V, VIII–X	
Length range cm	27–94	18–50	51–110	21–50	51–104
No. of stomachs examined	35	156	22	327	127
No. empty	5	22	1	40	15
No. with recognisable food	30	134	21	287	112
Percentage containing:					
CRUSTACEA	70	85	19	73	55
Decapoda ? spp.	—	—	—	12	8
Eupagurus	10	59	5	25	5
Portunus	—	10	10	10	14
Hyas	3	7	5	—	2
Corystes	—	—	—	5	21
Cancer	3	—	—	—	1
Stenorhynchus	3	—	—	—	—
Atelecyclus	—	—	—	+	—
Porcellana	—	—	—	1	—
Galathea	—	1	—	1	—
Munida	—	1	—	—	—
Crangon	50	3	—	2	1
Pandalus		2	—	—	1
Pycnogonum	—	1	—	—	—
Euphausiacea	—	—	—	+	—
Amphipoda	—	—	—	2	—
MOLLUSCA	—	2	10	3	5
Gasteropoda	—	—	—	1	4
Turritella	—	—	—	—	1
Lamellibranchiata	—	—	5	1	1
Solen (*Ensis*)	—	—	5	—	—

PISCES	13	9	76	34	71
Ammodytes	—	—	—	4	4
Gadus sp.	—	—	—	5	2
G. merlangus	—	1	10	1	3
G. callarias	—	—	—	—	1
Flatfish sp.	—	—	—	2	11
Solea sp.	—	—	—	1	1
Solea lutea	—	—	—	+	4
Limanda	—	1	14	1	4
Hippoglossoides	—	1	19	+	5
Callionymus	3	—	—	1	4
Onos	—	—	—	—	1
Clupea harengus	7	—	29	1	4
C. sprattus	—	—	—	1	—
Trigla	—	—	—	+	—
Raia radiata	—	—	—	+	—
Myxine	—	—	—	—	1
POLYCHAETA	10	1	—	9	15
Aphrodite	10	1	—	7	15
Sabellidae	—	—	—	+	—
NEMERTEA	—	—	—	+	—
OPHIUROIDEA	—	—	—	1	4
ANTHOZOA	—	—	—	1	—

THE SOUTHERN NORTH SEA (TABLE XV)

The southern half of the North Sea east of longitude 1° W and south of latitude 57° N is surveyed less frequently by Scottish research vessels than the northern half. In view of the small numbers of cod examined in most of the southern samples, it is convenient to combine all the records from this region, in which ecological conditions are variable. For comparative purposes the records have been considered under three periods.

Although half of the fish of all sizes examined from two samples (rectangles D10 and D12) in October 1922 were recorded as feeding on "shrimps" (presumably *Crangon* and *Pandalus*), only small proportions of the cod from the area as a whole in the periods 1928–35 and 1938–65 were eating these animals. The food of the 21–50 cm fish in each period consisted chiefly of Eupaguridae, *Portunus* and small fish of various species including gadoids, flatfishes and herring. The larger cod, though eating appreciable quantities of *Corystes*

(in at least one period) and *Portunus*, preyed more heavily on fish of which flatfishes, including soles, appeared in from 20 to 30 % of the stomachs. Relatively high proportions of the cod of both size-groups were found to be feeding on *Aphrodite aculeata*.

Todd (1905, 1907) studied the food of fishes in the southern North Sea, from 1903–1905. He found decapod crustaceans to be the principal food of the 664 cod which he examined, with *Eupagurus bernhardus* the outstanding single species occurring in the stomachs of most of the fish. Flatfishes and whiting were the commonest fishes eaten. Overall, crustaceans were eaten by 89 % (first report) and 80 % (second report) of the cod of all sizes, fish by 31 % and 36 %, polychaetes by 20 % and 13 %, molluscs by 12 % and 8 % and gephyreans and echinoderms by less than 1 % each. Considering the extent of the area as a whole and the different localities sampled in the two sets of observations, the results given in Table XV are in reasonably close agreement with those of Todd.

Graham (1924) dealt with the food of cod in the southern and central North Sea as determined by observers on commercial vessels. He was, however, mainly concerned with the food of large cod, so that his results are scarcely comparable with the present data. Nevertheless his identifications have on the whole been confirmed by the present work.

Perhaps the most surprising feature of the food in Table XV is the relative unimportance of sand eels in an area in which these fish are known to be sufficiently plentiful to support an industrial fishery. Macer (1966), from a study of the sand eel stocks of the southern North Sea, concluded that they do not represent an important item of food for fish in this region.

Aberdeenshire Coast

Rectangle C13, lying off the Aberdeenshire coast, has been sampled more frequently than any other rectangle in the Scottish area. In view of the numbers of cod examined and the variable ecological conditions within the area, the records have been considered under three sub-areas:

1. the relatively shallow Aberdeen Bay and its adjacent grounds (5–40 fm) in which the prevailing bottom deposits are sand and shells;
2. the deeper-water, though still sandy, depression of the Buchan Deep (55–65 fm);
3. the southern half of the rectangle stretching eastwards from Aberdeen Bay to Aberdeen Bank and including a number of depressions to a depth of 70 fm; the sea bottom in this section varies from sand and shells to hard rocky ground with silt in the depressions.

The stock in the area as a whole included cod of all sizes and appears to benefit by a seasonal incursion of of large fish towards the end of the year.

Aberdeen Bay (*Table XVI*)

The analyses of the cod food are arranged in three groups:–

(1) September to December 1921 and 1922, when the sizes of the fish were not grouped;

(2) January to December 1949–1957, when two size-groups were distinguished;

(3) March to May 1954–1958, when the sizes of individual cod were not known.

The material in the third group was procured just off the mouth of the River Dee by fishermen using the "ripper" method of hand-lining at the time when the major run of salmon smolts takes place from the river to the sea. The purpose of this investigation was to ascertain whether cod prey on smolts as they enter the sea. The stomachs from the fish in this group were examined in the laboratory, thus accounting for the more detailed identifications recorded at the foot of Table XVI.

Having regard to the differences in the years, the months, the size-groups, and to the fact that different members of the laboratory staff were responsible for the stomach analyses, the overall similarity in the composition of the food in the four columns of Table XVI is noteworthy. In each the commonest type is *Portunus*, with *Crangon* and *Pandalus* next in importance. The "ripper"-caught fish (1954–1958) were also feeding heavily on *Corystes* but this may reflect local sampling. Among the 19 species of fish preyed upon, sand eels were the prime food in each period, although the 1921–1922 samples showed that whiting clearly were eaten

TABLE XVI

FOOD OF COD IN ABERDEEN BAY (B13d, C13ac)

Years	1921–22	1949–57		1954–58
Months	IX–XII	I–XII		III–V
Length range cm	21–111	21–50	51–108	25–100
No. stomachs examined	1,160	383	274	1,102
No. empty	271	75	32	371
No. with recognisable food	889	308	242	714
Percentage containing:				
CRUSTACEA	45	78	67	75
Decapoda ? spp.	4	4	2	19
Eupaguridae	2	9	8	2
Portunus	26	31	38	24
Hyas	—	3	7	3
Corystes	—	1	5	18
Atelecyclus	+	—	+	1
Carcinus	—	+	2	2
Cancer	—	1	—	2
Stenorhynchus	—	1	—	+
Galathea	—	5	2	1
Munida	—	1	+	+
Crangon	14	24	9	20
Pandalus		10	8	7
Amphipoda	—	—	—	2
Isopoda	—	+	—	1
MOLLUSCA	13	1	15	17
Lamellibranchiata	8	—	11	9
Ensis	8	—	11	7
Gasteropoda	—	—	+	+
Cephalopoda	+	1	2	2
PISCES	56	40	51	51
Ammodytes	25	21	17	25
Gadus sp.	—	+	1	1
G. merlangus	19	1	4	+
Flatfish sp.	—	1	3	3
Limanda limanda	+	1	2	1
Hippoglossoides	—	+	2	1
Clupea harengus	+	—	1	3
C. sprattus	+	—	—	1
Agonus	1	5	3	2
Callionymus lyra	—	+	1	+
Gobius sp.	+	—	+	1
Pholis gunnellus	—	1	—	+
Raia sp.	+	—	+	+
POLYCHAETA	3	2	5	20
Aphrodite	2	1	2	4
Arenicola	1	+	3	8
OPHIUROIDEA	+	1	1	2
ANTHOZOA	—	1	1	1

The following organisms were also found in stomachs of cod from Aberdeen Bay on rare occasions (numbers in brackets):

CRUSTACEA

Porcellana (6)
Xantho (1)
Hippolyte (2)
Mysidacea (1)

POLYCHAETA

Nephthys (4)
Pectinaria (1)
Glycera (1)

OPHIUROIDEA

Ophiopholis aculeata (1)
Ophiura texturata (4)
Ophiothrix fragilis (1)

PISCES

Cadus aeglefinus (2)
Gadus minutus (1)
Pleuronectes platessa (1)
Microstomus kitt (1)
Trigla gurnardus (1)
Trachinus vipera (1)
Onos cimbrius (3)
Zoarces viviparus (3)
Cottus spawn (4)

ANTHOZOA

Tealia (4)

ALGAE (3)

MOLLUSCA

Venus (1)
Dosinia (2)
Mytilus (1)
Donax (1)
Mya (2)
Fusus (1)
Sepiola (7)
Eledone (6)
Loligo (2)
Cephalopoda spawn (1)

ASCIDIACEA (2)

TABLE XVII

FOOD OF SMALLER COD (21—50 CM) IN BUCHAN DEEP (C13b, C14d) 1952—1959

Months	January	February	Apr.—May	June	July—Aug.	Nov.—Dec.	Totals
Length range cm	23–50	21–50	21–50	21–50	21–50	25–50	21–50
No. stomachs examined	42	94	162	66	113	66	543
No. empty	7	19	28	8	29	16	107
No. with recognisable food	35	75	134	58	84	50	436
Percentage containing:							
CRUSTACEA	94	85	88	86	69	84	84
Decapoda ? spp.	—	3	—	2	—	—	1
Eupaguridae	34	29	31	48	24	30	32
Portunus	3	9	18	8	14	12	13
Hyas	11	12	10	2	1	—	6
Atelecyclus	6	4	—	—	1	—	1
Corystes	—	—	1	—	—	—	+
Galathea	9	19	4	2	—	—	5
Munida	—	—	1	—	1	—	1
Crangon	34	9	5	5	4	4	8
Pandalus	6	17	9	3	11	6	9
Hippolyte	—	—	1	—	—	—	+
Euphausiacea	—	1	—	—	2	—	1
Isopoda	—	1	—	—	—	—	+
PISCES	26	20	23	12	37	36	25
Ammodytes	9	1	4	3	31	—	9
Gadus sp.	—	1	1	2	—	—	1
G. aeglefinus	—	1	—	—	—	—	+
G. merlangus	—	1	3	—	—	—	1
G. callarias	—	—	—	2	—	—	+
G. esmarkii	—	—	1	—	—	—	+
Flatfishes sp.	—	—	1	—	—	—	+
Hippoglossoides	3	—	—	—	1	2	1
Onos cimbrius	—	—	1	—	—	—	+
Callionymus lyra	—	1	—	2	—	—	+
Argentina sphyraena	—	—	1	—	—	—	+
Gobius sp.	3	—	—	—	—	—	+
MOLLUSCA	3	4	—	5	1	—	2
Lamellibranchiata	—	—	—	—	1	—	+
Cephalopoda	3	4	—	—	—	—	1
Sepiola sp.	3	3	—	—	—	—	1
Gasteropoda	—	—	—	3	—	—	+
POLYCHAETA	3	7	2	5	1	—	3
Aphrodite	3	7	1	5	1	—	3
ANTHOZOA	3	—	1	—	—	—	+

TABLE XVIII

FOOD OF LARGER COD (51—118 CM) IN BUCHAN DEEP (C13b, C14d) 1952—1959

Months	January	February	Apr.—May	June	July—Aug.	Nov.—Dec.	Totals
Length range cm	51–118	51–110	51–118	51–105	51–114	51–103	51–118
No. stomachs examined	121	135	146	58	36	23	519
No. empty	23	22	21	10	8	4	88
No. with recognisable food	98	113	125	48	28	19	431
Percentage containing:							
CRUSTACEA	48	58	55	63	65	63	56
Decapoda ? spp.	—	4	—	2	—	—	1
Eupaguridae	36	35	25	48	21	42	33
Portunus	6	11	6	8	25	11	9
Hyas	1	9	10	8	7	—	7
Atelecyclus	5	2	3	8	—	—	3
Stenorhynchus	—	1	1	—	—	—	+
Corystes	3	—	3	15	—	—	3
Nephrops	—	1	1	—	—	—	+
Galathea	1	2	—	—	—	—	1
Munida	—	—	1	—	—	5	+
Crangon	5	5	2	—	—	—	3
Pandalus	—	5	6	2	—	5	3
Hippolyte	—	2	—	—	—	—	+
Nika	—	1	—	—	—	—	+
Spirontocaris	—	1	—	—	—	—	+
PISCES	65	55	71	54	61	68	62
Ammodytes	3	4	7	—	11	—	4
Gadus sp.	6	6	2	17	11	—	6
G. aeglefinus	2	4	4	4	11	5	4
G. merlangus	13	17	17	10	4	5	14
G. esmarkii	—	—	1	—	—	—	+
Flatfishes sp.	—	1	1	—	—	—	+
Limanda limanda	—	1	—	—	—	—	+
Hippoglossoides	4	1	2	—	4	—	2
Microstomus	—	1	—	—	—	—	+
Clupea harengus	—	3	10	2	7	—	4
Onos cimbrius	—	1	3	—	—	—	1
Lumpenus	—	—	—	2	—	—	+
Gobius sp.	1	—	—	—	—	—	+
Raia sp. incl. ova	1	1	—	2	—	—	1
MOLLUSCA	9	4	2	—	—	—	4
Cephalopoda	4	4	1	—	—	—	2
Loligo	3	—	1	—	—	—	1
Eledone	1	—	—	—	—	—	+
Sepiola	—	1	—	—	—	—	+
Gasteropoda	5	—	1	—	—	—	1
Buccinum incl. spawn	5	—	1	—	—	—	1
POLYCHAETA	3	8	7	13	7	—	6
Aphrodite	3	8	7	13	7	—	6
ANTHOZOA	1	—	—	4	—	—	1

by a fairly high proportion of the cod. This probably reflects predation on the whiting moving inshore at the end of the year.

Attention must also be drawn to the relatively high proportions of the cod feeding on molluscs and to some extent on polychaetes. The predation on molluscs, especially the razor shell, *Ensis,* is the heaviest on this group of organisms so far encountered in these investigations. Five genera of polychaetes were represented in the stomachs, of which *Aphrodite* and *Arenicola* were outstanding. These records doubtless reflect to some extent the nature of the local bottom fauna.

Despite the close examination of the stomach contents in the laboratory, no evidence was found to indicate predation on salmon or sea trout smolts.

Buchan Deep (*Tables XVII–XIX*)

The fairly regular sampling of this rather limited area, from 12 to 20 miles east of Buchan Ness, over the ears 1952–1959, has made it possible to set out the analyses of the cod food on a monthly or bi-monthly basis. The food of the smaller size-group (Table XVIII) reveals a preponderance of decapod crustaceans, among

TABLE XIX

FOOD OF COD IN BUCHAN DEEP (C13b, C14d) 1922—1924

Months	VII, VIII, IX		
Length range cm	21–95		
No. stomachs examined	228		
No. empty	45		
No. with recognisable food	183		
Percentage containing:			
CRUSTACEA	89	PISCES	11
Eupaguridae	14	*Ammodytes*	1
Portunus	3	*Gadus aeglefinus*	2
Hyas	17	Flatfish sp.	1
Atelecyclus	9	*Limanda limanda*	1
Stenorhynchus	1	*Clupea harengus*	4
Nephrops	1	*Callionymus lyra*	1
Crangon }	32	*Triglops*	1
Pandalus }		MOLLUSCA	1
POLYCHAETA	1	Cephalopoda	1
Aphrodite	1	*Loligo*	1
ANTHOZOA	1	*Eledone*	1

which hermit crabs (Eupaguridae) are of supreme importance over the entire year. *Portunus, Hyas, Galathea, Crangon* and *Pandalus* are eaten fairly frequently, although apparently not with the same regularity throughout the year. This suggests a seasonal effect but the results are scarcely conclusive on this point.

Sand eels are the chief fish prey of the smaller cod and evidently reach their maximum importance during the summer.

Hermit crabs are also the main constituent of the crustacean food of the larger cod, occasionally being eaten by about half the fish. *Portunus* and *Hyas* are the next most important genera, but are much less important than the Eupaguridae. The larger fish, as in other areas, eat fewer *Crangon* and *Pandalus*.

On the whole the larger cod also eat more fish than crustaceans. In contrast to some areas, however, the fish preyed upon are mainly small gadoids, which appear in more than 20 % of the stomachs. Of the individual species, whiting, in 14 % of the stomachs, is of prime importance. Sand eels and herring are also eaten in some quantities during the summer. The regular appearance of *Aphrodite* in the stomachs of each size-group throughout almost the entire year is again worthy of note.

The stomach contents of 228 cod of different sizes, but obviously consisting mainly of small fish, from the summers of 1922–1924, are summarised in Table XIX. These are interesting in their general confirmation of the results obtained from the later investigations in 1952–1959.

Aberdeen Bay to Aberdeen Bank — C13cd, D13c (Table XX)

The food of the cod in this area consists chiefly of decapod crustaceans. In each size-group, *Hyas* was the commonest organism eaten with hermit crabs a close second. As in other areas the smaller cod ate more *Crangon* and *Pandalus* than did the larger fish, which appeared to prefer *Atelecyclus, Portunus* and *Nephrops*. Sand eels were the commonest fish species eaten by both size-groups, although cod of 51–110 cm preyed on a variety of species including gadoids (14 %), flatfishes (7 %) and herring (5 %). *Aphrodite* appeared in the stomachs of 9 % of the larger cod.

TABLE XX

FOOD OF COD OFF ABERDEEN (C13cd, D13c) 1922—1961

Months	III–IX, XI, XII				
Length range cm	21–50	51–110			
No. of stomachs examined	222	92			
No. empty	32	12			
No. with recognisable food	190	79			
Percentage containing:					
CRUSTACEA	84	66	PISCES	26	56
Decapoda ? spp.	4	6	*Ammodytes*	7	9
Eupaguridae	18	15	*Gadus* sp.	2	4
Portunus	8	9	*G. aeglefinus*	—	3
Hyas	22	22	*G. merlangus*	—	6
Atelecyclus	2	9	*G. esmarkii*	+	1
Corystes	+	—	Flatfish sp.	—	6
Ebalia	+	1	*Hippoglossoides*	—	1
Stenorhynchus	+	3	*Clupea harengus*	—	5
Nephrops	+	6	*Callionymus lyra*	1	3
Galathea	3	1	*Gobius*	+	—
Munida	1	—	ova ? sp.	+	—
Crangon	15	5	MOLLUSCA	4	5
Pandalus	11	9	Gasteropoda	2	1
Pontophilus	—	1	Nudibranchiata	+	—
Balanus	1	—	Cephalopoda	+	1
Euphausiacea	1	—	*Sepiola*	+	—
POLYCHAETA	3	9	*Dentalium*	—	3
Aphrodite	2	9	ANEMONE	1	1
Arenicola	+	—			

EAST OF TURBOT BANK — E13 (TABLE XXI)

The results of the food investigations in this rectangle were such as to justify their being considered separately from those of adjacent areas. Decapod crustaceans again proved to be the main food of the 21–50 cm cod. Eupagurids, *Hyas* and *Galathea* are shown to be the commonest animals eaten, with *Crangon, Portunus, Pandalus* and *Atelecyclus* playing a less important role. The small cod on these grounds, however, show a greater interest in fish than elsewhere and sand eels appear in 11 % of the stomachs.

The diet of the larger cod, although including a fairly high proportion of hermit crabs, reveals a marked change-over from crustaceans to fish when compared with that of most of the areas considered so far. Rather surprisingly, however, not a single big cod was found to be feeding on sand eels, but over 30 % had eaten pelagic fish, including herring (in 19 % of the stomachs) and mackerel (15 %). Nearly 20 % of this size-group had eaten small gadoids, of which the commonest was *Gadus esmarkii* (in 9 % of the stomachs) and about 15 % had preyed on flatfishes.

GREAT FISHER BANK—G,H,J,K 13 AND EAST BANK—H14 (TABLE XXII)

Sampling was confined to the northern half of the Great Fisher Bank and to East Bank, where depths range mainly from 35 to 45 fm and the nature of the bottom varies from fine sand and mud to very rough ground with

TABLE XXI

FOOD OF COD TO THE EAST OF TURBOT BANK (E13)

Years	1953–58	
Months	III–XII	
Length range cm	21–50	51–112
No. stomachs examined	154	134
No. empty	21	36
No. with recognisable food	132	97
Percentage containing:—		
CRUSTACEA	66	22
Decapoda ? spp.	5	2
Eupaguridae	16	10
Portunus	6	—
Hyas	12	3
Corystes	2	1
Atelecyclus	5	3
Geryon	—	2
Ebalia	—	1
Galathea	10	—
Munida	2	—
Crangon	8	—
Pandalus	5	—
Hippolyte	2	—
Euphausiacea	1	—
Amphipoda	1	—
MOLLUSCA	2	3
Gasteropoda	—	1
Buccinum	—	1
Cephalopoda	1	1
Eledone	—	1
Loligo	1	—
PISCES	46	91
Ammodytes	11	—
Gadus sp.	1	3
G. merlangus	1	5
G. aeglefinus	—	3
G. esmarkii	3	9
Flatfish sp.	2	6
Limanda limanda	—	4
Hippoglossoides	2	6
Microstomus kitt	1	—
Clupea harengus	—	19
C. sprattus	—	1
Scomber scombrus	—	15
Gobius	1	1
Raia	—	1
POLYCHAETA	2	2
Aphrodite	2	2

TABLE XXII

FOOD OF COD IN GREAT FISHER BANK AREA (G13, H13, J13, K13) AND EAST BANK (H14)

Years	1953–63	
Months	III–XI	
Length range cm	21–50	51–120
No. stomachs examined	117	105
No. empty	25	23
No. with recognisable food	91	80
Percentage containing:		
CRUSTACEA	37	46
Decapoda ? spp.	4	4
Eupaguridae	9	8
Portunus	3	5
Hyas	1	24
Corystes	—	1
Crangon	2	1
Pandalus	3	—
Mysidacea	1	—
Amphipoda	2	—
MOLLUSCA	8	9
Lamellibranchiata	—	1
Gasteropoda	6	8
ECHINODERMATA	1	1
Echinoidea	—	1
Ophiuroidea	1	—
PISCES		
Ammodytes	62	81
Gadus sp.	3	—
G. merlangus	2	4
G. aeglefinus	—	15
G. esmarkii	—	1
Flatfish sp.	12	6
Limanda	1	3
Hippoglossoides	—	4
Glyptocephalus	1	3
Clupea harengus	—	1
Scomber scombrus	—	5
Trigla	3	11
POLYCHAETA	—	3
Aphrodite	9	13
Nephthys	2	13
Phyllodoce	2	—
	1	—

dense concentrations of hydroids and polyzoans. Large cod are more plentiful in this area than in most of those already considered. Some spawning occurs, and fish with well-developed reproductive organs are occasionally found here, as in some other parts of the North Sea, from mid-August onwards (Rae, 1964). Although this suggests an early, out-of-season spawning (and there is some evidence to support this from the condition of the ova in some of these fish) it is not known whether spawning on any marked scale actually occurs at this time of year.

There is a difference in the food of the smaller cod compared with other areas, namely that it consists predominantly of fish. Eupagurids are the commonest type of crustacean eaten by the smaller fish and of the fish types *Gadus esmarkii* is the outstanding species.

The larger cod on the other hand prey chiefly on *Hyas* and to a less degree on hermit crabs and *Portunus*. Of the fish types, gadoids appear in about 25 % of the stomachs (whiting in 15 %), flatfishes in 11 %, mackerel in 11 % and herring in 5 %.

On this ground gasteropods (8 %), and *Aphrodite* (13 %) were well represented in the stomachs.

TABLE XXIII

FOOD OF COD IN INNER MORAY FIRTH (A14)

Years	1921–24	1952–1963					
Months	II, VIII, IX, XI, XII	I–VI, VIII, X, XI					
Length range cm	21–109	21–50	51–90				
No. stomachs examined	523	258	133				
No. empty	159	24	17				
No. with recognisable food	364	234	116				
Percentage containing:							
CRUSTACEA	67	32	45	PISCES	40	86	76
Decapoda ? spp.	21	1	1	*Ammodytes*	2	35	39
Eupaguridae	10	1	2	*Gadus* sp.	—	1	3
Portunus	5	9	22	*G. merlangus*	8	—	—
Hyas	1	+	—	*G. aeglefinus*	+	—	—
Atelecyclus	—	—	1	Flatfish sp.	—	1	9
Nephrops	14	1	22	*Limanda limanda*	3	—	3
Galathea	—	6	3	*Hippoglossoides*	2	1	2
Munida	—	1	1	*Microstomus*	+	—	—
Crangon	5	6	3	*Glyptocephalus*	1	—	—
Pandalus	5	6	2	*Platichthys*	+	—	—
Isopoda	—	+	1	*Solea lutea*	1	—	—
Amphipoda	—	+	—	*Clupea* sp.	—	+	3
MOLLUSCA	1	1	3	*C. harengus*	1	33	11
Gasteropoda	+	+	1	*C. sprattus*	—	3	—
Cephalopoda	—	+	2	*Agonus*	2	2	2
POLYCHAETA	2	—	—	*Callionymus lyra*	+	+	3
Aphrodite	2	—	—	*Trigla gurnardus*	—	+	—
OPHIUROIDEA	—	—	2	*Pholis gunnellus*	1	—	—
				Chirolophis	+	—	—
				Spinachia	+	—	—
				Syngnathus	+	—	—
				Myxine glutinosa	+	—	—
				Raia batis	—	—	1

MORAY FIRTH

In view of the variable depth and ecological conditions in the Moray Firth and the incidence of the sampling, the area has been conveniently sub-divided according to the statistical rectangles.

The inner firth — A14 (Table XXIII)

In the inner firth the grounds sampled range in depth from 10 to 40 fm and the bottom deposits consist chiefly of sand and mud. Table XXIII summarises the food analysis for two distinct periods in the first of which no distinction was made in the size of the cod.

In marked contrast to those in the areas already considered the smaller fish were feeding predominantly on fish, and, even more surprisingly, a higher proportion of this size-group was feeding on fish than in the larger size-group. The smaller cod preyed on *Portunus, Galathea, Crangon* and *Pandalus* but by far the commonest food types were small sand eels (in 35 %) and small herring (in 33 %).

The larger cod preyed heavily on *Portunus* and *Nephrops* (each in 22 % of the fish) but even more so on sand eels (in 39 %). Herring were taken less frequently, by 11 %, while flatfishes were eaten by 14 % of the fish.

In each size-group predation on small herring was concentrated mainly in the early part of the year (this was particularly noticeable in February 1959); sand eels on the contrary were eaten more or less throughout

TABLE XXIV

FOOD OF COD IN NORTH-WESTERN MORAY FIRTH (A15)

Years	1921	1921–1963	
Months	XI	II, III, V, VI, VIII–XI	
Length range cm	30–90	21–50	51–110
No. stomachs examined	58	96	57
No. empty	19	12	18
No. with recognisable food	39	84	39
Percentage containing:			
CRUSTACEA	21	42	46
Decapoda ? spp.	13	6	3
Eupaguridae	3	1	5
Portunus	—	12	21
Hyas	—	1	3
Atelecyclus	—	1	—
Gonoplax	—	1	—
Nephrops	—	1	10
Galathea	—	7	—
Munida	—	4	—
Crangon	—	1	—
Pandalus	—	2	—
MOLLUSCA	3	5	3
Cephalopoda	3	5	3
Sepiola	—	1	—
PISCES	77	57	64
Ammodytes	—	39	18
Gadus merlangus	23	—	10
G. aeglefinus	10	—	3
G. esmarkii	—	5	—
Limanda limanda	8	1	8
Microstomus kitt	—	—	3
Trigla gurnardus	—	—	3
Callionymus lyra	—	1	3
Agonus	—	1	5
POLYCHAETA	—	1	5
Aphrodite	—	—	5
OPHIUROIDEA	—	2	3

the year although rather more heavily in May than at other times. These records indicate predation of a seasonal nature.

Unlike most of the previous comparisons with records from earlier years, the 1921–1924 results from the inner Moray Firth are in most respects different from those of 1952–1963. *Nephrops*, hermit crabs and whiting are the commonest types eaten in the 1920's, but it should be noted that sampling in these years was confined mainly to the second half of the year so that the results may again indicate a possible seasonal effect in the feeding. Moreover, from the presence of various shore fishes in these earlier records, it would appear that some of the samples at least were obtained from estuarine waters or from close inshore and for this reason too would not be truly comparable with those of 1952–1963. They nevertheless demonstrate the ability of the cod to extend its range of predation to marginal localities.

North-western section — A15 (Table XXIV)

In this relatively small area depths range from 20 to 40 fm and the bottom is almost entirely of sand.

The food of cod resembles that in the inner firth in the preponderance of fish in the diet of both size-groups. In this area, too, *Portunus* is the outstanding decapod food of both size-groups with *Nephrops* second in importance in the diet of the larger fish. Sand eels are the predominant species among the fish eaten, particularly

TABLE XXV

FOOD OF COD IN SOUTH-EASTERN MORAY FIRTH (B14)

Years	1924	1949–1963	
Months	IV, VI, VII	I–VIII, X–XII	
Length range cm	21–109	21–50	51–100
No. stomachs examined	34	135	160
No. empty	1	23	17
No. with recognisable food	33	111	143
Percentage containing:			
CRUSTACEA	82	74	78
Decapoda ? spp.	—	14	3
Eupaguridae	6	1	2
Portunus	12	19	13
Hyas	12	1	1
Atelecyclus	6	—	1
Geryon	—	—	1
Gonoplax	—	—	1
Cancer	3	—	—
Nephrops	36	3	39
Galathea	—	9	7
Munida	15	3	1
Calocaris	—	1	—
Crangon	—	15	10
Pandalus	3	6	14
Hippolyte	—	1	—
Euphausiacea	—	—	1
MOLLUSCA	3	—	7
Lamellibranchiata	—	—	1
Gasteropoda	—	—	1
Cephalopoda	3	—	6
Sepiola	—	—	1
Eledone	—	—	1
Loligo	—	—	1
POLYCHAETA	3	1	2
Aphrodite	3	—	1
Glycera	—	1	—
PISCES	21	50	42
Ammodytes	—	26	10
Gadus sp.	—	—	3
G. aeglefinus	3	—	—
G. esmarkii	—	—	1
Flatfish sp.	—	6	2
Limanda limanda	—	2	1
Hippoglossoides	3	—	3
Microstomus kitt	—	—	1
Zeugopterus	—	1	—
Clupea harengus	—	—	3
C. sprattus	—	—	1
Merluccius	—	—	1
Trigla gurnardus	—	—	1
Agonus	—	1	—
Lumpenus	3	1	1
Gobius	3	1	1
Triglops murrayi	—	1	—
Pholis gunnellus	—	—	1
Callionymus lyra	—	1	1
Onos cimbrius	3	—	—
Blennius	3	—	—
OPHIUROIDEA	6	1	1

in the 21 to 50 cm size-group (39 %). The larger cod also prey on gadoids (including 10 % on whiting) and flatfishes (including 8 % on common dabs).

Stomachs from cod of various sizes in November 1921 are interesting in showing none feeding on sand eels but 33 % on gadoids (including 23 % on whiting). This is regarded as further evidence of seasonal differences in the feeding which are dependent on the availability of the prey.

South-eastern section — B14 (Table XXV)

Depths over the greater part of this area are from 10 to 50 fm but a deep trench, 50 to 80 fm deep, runs from east to west with small depressions of over 100 fm near its eastern end. The bottom is largely of sand with mud in the trench and other deeper parts. There is also some hard ground.

The food from 1949 to 1963 shows the continuing importance of *Portunus* and an increase, compared with other parts of the Moray Firth, in the numbers of cod of all sizes feeding on *Crangon* and *Pandalus*. To the large cod, which are relatively more numerous than in many other coastal areas, the outstanding food type is *Nephrops*.

Despite the presence of 19 species of fish only one species, the sand eel, is eaten in any quantity. Flatfishes as a group, however, are fairly well represented in the food, as are also various species of no commercial importance. Samples procured in the spring and summer of 1924 reveal a very high proportion (36 %) of cod feeding on *Nephrops* and smaller numbers on *Hyas* and *Munida* but no evidence of sand eels. It is clear, however, that these samples were obtained from the deep-water trench where *Nephrops* are plentiful and not from the sandy ground where sand eels might be expected.

TABLE XXVI

FOOD OF COD IN NORTH-EASTERN MORAY FIRTH (B15)

Years	1921–22	1949–63					
Months	II, IX	I–III, V–XII					
Length range cm	26–95	21–50	51–99				
No. stomachs examined	67	259	90				
No. empty	14	40	12				
No. with recognisable food	53	219	78				
Percentage containing:							
CRUSTACEA	79	35	33	PISCES	25	71	90
Decapoda ? spp.	51	9	—	*Ammodytes*	—	63	69
Eupaguridae	26	5	5	*Gadus* sp.	—	—	3
Portunus	—	6	10	*G. merlangus*	13	—	5
Hyas	4	5	3	*G. minutus*	—	—	1
Atelecyclus	—	1	3	*Hippoglossoides*	—	1	3
Gonoplax	—	—	1	*Microstomus*	—	+	—
Carcinus	—	—	1	*Limanda limanda*	4	—	—
Nephrops	—	1	10	*Callionymus* sp.	2	+	—
Galathea	—	4	3	*Agonus*	—	+	1
Crangon	—	1	1	*Gobius* sp.	—	+	—
Pandalus	—	+	1	POLYCHAETA	—	—	1
Euphausiacea	—	+	—	ECHINODERMATA	—	1	3
MOLLUSCA	4	1	3	Ophiuroidea	—	1	1
Lamellibranchiata	2	—	1	Asteroidea	—	—	1

North-eastern section — B15 (Table XXVI)

This area, ranging in depth from 20 to 60 fm, includes the Smith and Bitickie Banks where sand and shells are the prevailing bottom deposits. In the deeper water of the eastern half of the rectangle there are patches of mud interspersed with rough ground. Young fish predominate in this area.

The food of both size-groups consists overwhelmingly of fish, with sand eels occurring in 60 to 70 % of the stomachs. The crustacean component of the food of the 21–50 cm size-group is made up equally of hermit crabs, *Portunus*, *Hyas* and *Galathea*, but rather surprisingly includes few shrimps. The stomachs of the larger cod reveal mixed feeding on decapods, with *Portunus* and *Nephrops* occurring more frequently than the other types, and on various gadoids.

Sampling in February and September of 1921 and 1922 reveals an extensive predation on eupagurids and on whiting but no indication of sand eels. This suggests seasonal feeding on whiting in autumn and winter, and that sand eels are eaten in spring and summer when these fish are most plentiful in this area.

TABLE XXVII

FOOD OF COD EAST OF MORAY FIRTH (C14ab, C15)

Years	1922–1953		
Months	I–IV, VII, XII		
Length range cm	24–98		
No. stomachs examined	101		
No. empty	29		
No. with recognisable food	72		
Percentage containing:			
CRUSTACEA	44	PISCES	63
Eupaguridae	10	*Ammodytes*	35
Portunus	1	*Gadus aeglefinus*	1
Hyas	6	Flatfish sp.	1
Stenorhynchus	3	*Hippoglossoides*	1
Nephrops	1	*Callionymus lyra*	1
Galathea	1	MOLLUSCA	3
Munida	1	Cephalopoda	1
Crangon	4	*Sepiola*	1
Pandalus	8	POLYCHAETA	3

TABLE XXVIII

FOOD OF COD ON THE FLADEN GROUND (D14, D15, E14, E15, E16, F14, F15)

Years	1924–62				
Months	I, II, IV–XII				
Length range cm	21–50	51–111			
No. stomachs examined	177	153			
No. empty	51	15			
No. with recognisable food	125	138			
Percentage containing:					
CRUSTACEA	69	54	PISCES	48	70
Decapoda ? spp.	7	3	*Ammodytes*	7	4
Eupaguridae	14	5	*Gadus* sp.	1	3
Portunus	6	2	*G. merlangus*	1	4
Hyas	2	—	*G. esmarkii*	2	8
Geryon	8	6	*G. poutassou*	—	1
Gonoplax	—	3	Flatfish sp.	2	1
Nephrops	10	30	*Hippoglossoides*	6	5
Crangon	6	1	*Clupea harengus*	—	17
Pandalus	13	9	*Scomber scombrus*	—	3
Hippolyte	1	—	*Argentina sphyraena*	—	1
Nika	1	—	*Callionymus lyra*	2	1
Amphipoda	1	—	*Onos* sp.	—	2
Isopoda	1	—	*Myxine glutinosa*	—	1
MOLLUSCA	2	1	POLYCHAETA	1	1
Gasteropoda	1	1	*Aphrodite*	1	1
Buccinum	1	1			
Cephalopoda	1	—			
Loligo	1	—			
Scaphopoda	1	—			
Dentalium	1	—			

Eastern approaches to the firth — C14 ab, C15 (Table XXVII)

Relatively few cod were examined from this area of variable depths and ecological conditions. Sand eels are again seen to be the principal food type even though sampling was confined mainly to the first four months and to December.

THE FLADEN GROUND — D14, 15; E14,15,16; F14,15 (TABLE XXVIII)

This extensive fishing ground, with its trawlable bottom consisting of mud and fine sand to a maximum depth of 90 fm, is not a very prolific ground for cod. Nevertheless, in this area cod of all sizes feed on a variety of decapods including most of the types commonly identified in the food elsewhere and, for the first time with some frequency, *Geryon tridens*, which occurs in some of the deeper parts of the northern North Sea. *Nephrops* is the outstanding item in the food of the larger cod which also prey on a variety of fish including herring (17 %) and small gadoids (16 %).

TABLE XXIX

FOOD OF COD IN THE LING BANK—CORAL BANK AREA (G15, H15)

Years	1955–62	
Months	III–VI, VIII–XI	
Length range cm	21–50	51–109
No. stomachs examined	153	172
No. empty	28	52
No. with recognisable food	121	118
Percentage containing:		
CRUSTACEA	55	24
Decapoda ? spp.	12	3
Eupaguridae	9	3
Portunus	1	3
Hyas	6	6
Galathea	1	—
Munida	—	1
Crangon	13	4
Pandalus	2	1
Hippolyte	1	—
Spirontocaris	1	—
Euphausiacea	—	1
Mysidacea	5	—
Amphipoda	1	—
Isopoda	1	1
MOLLUSCA	1	3
Gasteropoda	1	—
Cephalopoda	—	1
Eledone	—	1
PISCES	55	86
Ammodytes	1	—
Gadus sp.	—	3
G. merlangus	1	8
G. aeglefinus	—	2
G. esmarkii	5	3
Flatfish sp.	5	12
Limanda limanda	1	12
Hippoglossoides	7	13
Glyptocephalus	—	1
Clupea harengus	1	8
Scomber scombrus	2	24
Anarhichas lupus	—	1
Agonus	1	1
POLYCHAETA	2	8
Aphrodite	—	4
Phyllodoce	—	1
NEMERTEA	—	1

LING BANK – CORAL BANK AREA — G15; H15 (TABLE XXIX)

The sea bottom in this area is variable, both in depth and in the nature of the deposits. Sand and shells extend over the shallower parts at depths of 35–50 fm but in the rough north-eastern sector the water deepens in places to 80 fm where the bottom consists of mud. Large cod are relatively numerous on these grounds where spawning is known to occur. In this connection it is appropriate to draw attention to the rather high proportion of empty stomachs in the larger size-group, which may, to some extent, temporarily reflect a partial cessation of feeding during spawning. This feature will be discussed later.

The food of the 21–50 cm size-group consists equally of decapods and fish. Among the former, hermit crabs, *Hyas* and *Crangon* appear to be the favoured types, while young flatfishes, many of them at the post-larval stage, are prominent among the fish types.

The larger cod prey heavily on a variety of fish types but appear to be particularly partial to flatfishes and mackerel. Nearly 40 % of this size-group were feeding on flatfishes — the heaviest predation on this group

TABLE XXX

FOOD OF COD ON EAST ORKNEY GROUNDS (B16, B17, C16, C17)

Years	1928–1963	
Months	I–XII	
Length range cm	21–50	51–96
No. stomachs examined	233	54
No. empty	29	2
No. with recognisable food	204	52
Percentage containing:		
CRUSTACEA	50	44
Decapoda ? spp.	5	15
Eupaguridae	10	8
Portunus	5	—
Hyas	6	2
Atelecyclus	1	2
Ebalia	+	—
Geryon	—	2
Nephrops	1	13
Galathea	4	—
Munida	1	—
Crangon	2	—
Pandalus	10	2
Euphausiacea	+	—
MOLLUSCA	5	—
Lamellibranchiata	+	—
Cephalopoda	3	—
Sepiola	1	—
Eledone	+	—
PISCES	65	71
Ammodytes	45	44
Gadus sp.	—	2
G. merlangus	—	2
G. esmarkii	4	2
G. minutus	+	—
Flatfish sp.	+	—
Limanda limanda	—	2
Hippoglossoides	+	2
Microstomus	—	2
Zeugopterus	+	—
Clupea harengus	—	10
Agonus	+	—
Gobius sp.	1	—
POLYCHAETA	—	2
Nephthys	—	2

TABLE XXXI

FOOD OF COD ON GROUNDS FROM FOULA AND SCALLOWAY DEEP TO EAST OF FAIR ISLE (C18, C19, D16, D17, D18)

Areas	C18, 19		D16, 17, 18	
Years	1924–60		1928–59	
Months	III–VII, XI		III–XI	
Length range cm	21–50	51–65	24–50	51–115
No. stomachs examined	222	21	117	114
No. empty	19	4	21	36
No. with recognisable food	203	17	96	77
Percentage containing:				
CRUSTACEA	30	—	57	53
Decapoda ? spp.	—	—	3	4
Eupaguridae	11	—	6	5
Portunus	4	—	4	3
Hyas	5	—	5	3
Atelecyclus	—	—	2	—
Geryon	—	—	5	19
Xantho	—	—	1	—
Ebalia	—	—	—	1
Gonoplax	—	—	—	1
Nephrops	—	—	2	10
Galathea	1	—	1	—
Crangon	1	—	9	3
Pandalus	6	—	17	6
Euphausiacea	+	—	—	—
Amphipoda	—	—	1	—
MOLLUSCA	1	—	—	—
PISCES	77	94	53	64
Ammodytes	69	41	—	—
Gadus sp.	—	—	4	1
G. merlangus	—	—	2	1
G. aeglefinus	+	—	—	1
G. esmarkii	—	—	3	6
Flatfish sp.	—	—	1	1
Hippoglossoides	—	—	7	4
Glyptocephalus	—	—	—	1
Clupea harengus	+	6	3	30
Onos cimbrius	—	—	—	3
Callionymus	+	—	—	—
Liparis	+	—	—	—
Triglops	+	—	—	—
POLYCHAETA	+	6	5	1
Aphrodite	+	6	3	1

experienced so far in these studies. The commonest individual species in the food was mackerel (in 24 % of the stomachs) while gadoids were eaten by 15 % of the fish.

EAST ORKNEY — B16, 17; C16, 17 (TABLE XXX)

This area comprises grounds on the eastern side of Orkney from the Moray Firth northwards to latitude 59° 30′ N and eastwards to longitude 1° W. The sea bottom over its major part consists of sand and shells at depths of 30–60 fm, but some rough ground occurs at greater depths towards its eastern edge. The cod stock is mainly composed of young fish.

On average, fish are eaten more frequently than decapod crustaceans by cod of both size-groups in this area. Sand eels are by far the commonest food type, being eaten by more than 40 % of the cod in each group.

TABLE XXXII

FOOD OF COD ON EAST SHETLAND GROUNDS (D19, D20, D21, see Fig. 1)

Years	1924–1962				
Months	II–XII				
Length range cm	21–50	51–109			
No. stomachs examined	251	234			
No. empty	40	42			
No. with recognisable food	211	192			
Percentage containing:					
CRUSTACEA	85	54	PISCES	23	67
Decapoda ? spp.	4	5	*Ammodytes*	7	4
Eupaguridae	16	9	*Gadus* sp.	1	3
Portunus	5	3	*G. aeglefinus*	—	6
Hyas	11	7	*G. esmarkii*	1	1
Atelecyclus	6	11	*G. minutus*	+	1
Stenorhynchus	+	1	Flatfish sp.	2	7
Lithodes	+	1	*Limanda limanda*	—	1
Corystes	1	—	*Hippoglossoides*	1	1
Nephrops	+	1	*Microstomus*	1	2
Galathea	21	4	*Lepidorhombus*	—	1
Munida	16	13	*Glyptocephalus*	—	1
Crangon	8	2	*Clupea harengus*	—	5
Pandalus	12	4	*Scomber scombrus*	—	1
Hippolyte	—	1	*Molva molva*	—	1
Euphausiacea	1	1	*Merluccius*	—	1
Isopoda	+	—	*Onos* sp.	—	1
MOLLUSCA	2	5	*Gobius* sp.	1	1
Lamellibranchiata	1	—	*Argentina sphyraena*	1	2
Gasteropoda	1	2	*Trigla gurnardus*	—	1
Cephalopoda	—	3	*Callionymus* sp.	+	4
Scaphopoda	1	1	*Chirolophis*	—	1
POLYCHAETA	3	3	*Raia* sp.	—	1
Aphrodite	—	2	*Scyliorhinus* (egg)	—	1
ECHINODERMATA	—	1	HYDROIDEA	—	1
Echinoidea	—	1			
Ophiuroidea	—	1			

The smaller cod also prey moderately on *Eupagurus* and *Pandalus* and the larger fish on *Nephrops*, *Eupagurus* and herring.

An examination of individual samples from the vicinity of the Pentland Skerries (B16) shows that, although during the summer 100 % of the cod of all sizes may feed on sand eels, predation on this food type is not confined to this time of year, and that from 44 to 68 % of the cod have in different years been found to be feeding on sand eels from December to February.

FOULA, SCALLOWAY DEEP AND FAIR ISLE AREAS (TABLE XXXI)

The food analyses of cod in these areas are summarised separately in Table XXXI.

Foula — Scalloway Deep — C18,19

In this relatively small locality depths range mainly from 30 to 70 fm and the bottom consists almost ıtirely of sand and shells. The cod examined were mostly less than 51 cm in length. Sand eels were the out-anding food type with hermit crabs, *Portunus, Hyas* and *Pandalus* next in importance.

East of Fair Isle — D16,17,18

In these rectangles the water is mainly from 60 to 80 fm deep and the bottom deposits of sand and mud.)ecapods and fish are preyed upon by both groups of cod in about equal proportions. Most of the common ecapod types appear in the food. *Crangon* and *Pandalus* are prominent in the diet of the smaller fish and *Geryon*

TABLE XXXIII

FOOD OF COD IN THE CENTRAL NORTHERN NORTH SEA (E17—22, F16—22, G16—21, H16—19)

	*						
ears	1922–24	1928–62					
lonths	VI–VIII	II–XI					
ength range cm	23–104	21–50	51–116				
lo. stomachs examined	69	319	359				
lo. empty	9	62	67				
lo. with recognisable food	60	257	292				
ercentage containing:							
CRUSTACEA	63	51	39	PISCES	55	54	79
Decapoda ? spp.	—	2	4	*Ammodytes*	—	—	1
Eupaguridae	3	13	4	*Gadus* sp.	—	5	9
Portunus	5	4	2	*G. merlangus*	—	1	3
Hyas	3	7	1	*G. aeglefinus*	2	2	3
Geryon	47	2	6	*G. esmarkii*	5	6	3
Atelecyclus	—	—	1	*G. poutassou*	—	—	2
Xantho	—	—	1	*Gadiculus*	—	1	—
Lithodes	—	—	1	Flatfish sp.	—	3	4
Nephrops	7	2	9	*Limanda limanda*	2	1	2
Galathea	—	4	3	*Hippoglossoides*	—	6	7
Munida	—	2	3	*Glyptocephalus*	2	—	1
Crangon	—	3	1	*Clupea harengus*	35	—	12
Pandalus	—	4	4	*Scomber scombrus*	—	1	4
Hippolyte	—	—	+	*Onos* sp.	—	—	+
Euphausiacea	—	1	—	*Trigla gurnardus*	—	+	1
Isopoda	—	1	+	*Argentina* sp.	—	—	1
MOLLUSCA	—	5	3	*Callionymus* sp.	—	—	1
Lamellibranchiata	—	+	1	*Lophius*	—	—	+
Gasteropoda	—	+	1	*Merluccius*	—	—	+
Cephalopoda	—	1	2	*Sebastes* sp.	—	+	—
Scaphopoda	—	+	—	*Raia* sp. (egg)	—	—	1
Dentalium	—	+	—	POLYCHAETA	2	+	4
OPHIUROIDEA	2	—	2	*Aphrodite*	2	+	4

* Statistical rectangles E18, 19; G20 only

ıd *Nephrops* in that of the larger cod. Gadoids and flatfishes are represented in the food of both size-groups but :rring (in 30 % of the stomachs) are clearly the chief food of the larger fish, especially during the summer :onths.

AST SHETLAND — D19,20,21 (TABLE XXXII)

In the coastal waters of East Shetland depths range from 60 to 80 fm in rectangles D19, 20, and increase 100 fm or more in D21. Over most of this area trawling is possible on a bottom of fine sand or mud. Most

of the fish sampled were less than 51 cm in length and a high proportion of the others fell within the 51–70 cm size-range.

The food of the 21–50 cm group consists predominantly of decapods, among which *Galathea* appears as the leading type with *Munida*, eupagurids, *Pandalus* and *Hyas* next in order of importance. Of the fish types only sand eels appear to be eaten in any quantity.

At least twelve different decapod crustaceans appear in the food of the larger cod. Of these *Munida* and *Atelecyclus* were found respectively in 13 % and 11 % of the stomachs, but hermit crabs and *Hyas* were also eaten fairly commonly. The fish preyed upon by this size-group include at least 21 different species, each of which appears in from 1 to 6 per cent of the stomachs; haddock, herring, sand eels and *Callionymus* were eaten most frequently although flatfishes as a group were taken by 13 % of the cod.

Central Northern North Sea (Table XXXIII)

This comprehensive region stretches eastwards from the Greenwich Meridian to the western edge of the Norwegian Deep, and from latitude 58° 30′ N northwards to latitude 62° N (Figure 1). As may be expected in

TABLE XXXIV

FOOD OF COD ON NORTH-WEST SHETLAND GROUNDS (B19, B20, C20, C21)

Years	1930–58		
Months	II–V, VII, IX–XI		
Length range cm	31–93		
No. stomachs examined	71		
No. empty	11		
No. with recognisable food	60		
Percentage containing:			
Crustacea	67	Pisces	37
Decapoda ? spp.	12	*Gadus esmarkii*	17
Eupaguridae	7	*Clupea harengus*	3
Portunus	—	*Scomber scombrus*	3
Hyas	2	Mollusca	13
Atelecyclus	18	Gasteropoda	3
Xantho	2	Cephalopoda	2
Pinnotheres	3	*Dentalium*	12
Galathea	7	Polychaeta	15
Munida	22	*Aphrodite*	12
Crangon	3	Ophiuroidea	3
Pandalus	2		
Pontophilus	8		
Nika edulis	3		
Isopoda	2		

an area where depths range from 50 to 200 fm the nature of the sea bed varies considerably, but most of the trawling for cod was carried out in 60–120 fm. The stock of cod included a much higher proportion of large fish than in any other part of the North Sea.

Decapods and fish are eaten in roughly equal proportions by the smaller cod. Hermit crabs and *Hyas* are the commonest types but, as in other northern areas, the variety of decapods eaten is greater than in the south. Small gadoids were eaten by 15 % and flatfishes by 10 % of the fish in this size-group.

The food of the larger cod includes at least 13 decapod types, of which *Nephrops* (in 9 % of the stomachs) is the outstanding single species. Of the fish eaten, herring (in 12 % of the stomachs) is the commonest individual species, but the bulk of the food would seem to consist of gadoids (in 20 %) and flatfishes (in 14 %).

A number of samples taken from June to August in 1921–1924, in which years the sizes of the cod were not distinguished, are interesting in showing cod to be feeding very heavily on *Geryon tridens* and on herring. The concentration of the cod on these two types was particularly marked in rectangle E18 where 67 % of the

stomachs contained *Geryon* and 43 % herring in August 1922. These observations would seem to provide further evidence of seasonal and local concentrations in the feeding of cod.

North-West Shetland — B19,20; C20,21 (Table XXXIV)

In this area sampling was carried out at depths ranging from 50 to 100 fm on a sea bottom which varied from sand and shells to hard ground. In view of the small number of cod of all sizes the records have been combined. These are interesting in demonstrating the overall importance of decapods in the food. Not only

TABLE XXXV

FOOD OF COD ON NORTH OF SCOTLAND GROUNDS (A16, A17, A18, ZZ16, ZZ17, ZZ18)

Rectangles	A16, ZZ16		A17, 18; ZZ17, 18				
Years	1950–1963		1930–59				
Months	II, III, V–XI		III–VI, IX–XI				
Length range cm	21–50	51–102	35–109				
No. stomachs examined	182	319	109				
No. empty	12	41	13				
No. with recognisable food	170	277	96				
Percentage containing:							
Crustacea	22	26	58	Pisces	91	87	48
Decapoda ? spp.	1	—	13	*Ammodytes*	84	73	18
Eupaguridae	2	4	2	*Gadus* sp.	1	3	2
Portunus	7	6	9	*G. merlangus*	1	—	1
Hyas	4	5	3	*G. esmarkii*	1	+	1
Atelecyclus	—	5	5	*G. minutus*	—	—	1
Corystes	1	+	—	Flatfish sp.	1	1	—
Stenorhynchus	—	1	2	*Limanda*	1	—	2
Ebalia	—	1	—	*Microstomus*	—	—	1
Xantho	—	1	—	*Clupea harengus*	—	—	2
Nephrops	—	—	5	*Callionymus*	1	2	1
Galathea	6	3	2	*Agonus*	—	1	—
Munida	1	3	11	*Lumpenus*	—	+	1
Crangon	1	1	—	*Lepadogaster*	1	—	—
Pandalus	5	10	11	*Raia* sp.	—	+	1
Hippolyte	1	+	—	Mollusca	2	2	4
Isopoda	—	—	1	Lamellibranchiata	—	1	1
Polychaeta	1	1	—	*Pecten*	—	+	—
Aphrodite	—	+	—	*Chlamys*	—	—	1
Echinodermata	1	2	1	Gasteropoda	1	+	—
Holothuroidea	1	—	—	*Natica*	—	+	—
Ophiuroidea	—	2	1	Cephalopoda	1	1	3
Ophiothrix	—	1	—	*Sepiola*	—	1	—
Hydroidea	—	+	—	*Rossia*	1	—	—
				Eledone	—	—	1

re eleven different decapod types represented in the comparatively small number of stomachs examined but he outstanding items, *Atelecyclus, Munida* and *Pontophilus,* are distinct from those in most of the areas examined so far. Among the fish types, *Gadus esmarkii,* in 17 % of the stomachs, attains its highest frequency yet recorded in these studies. Molluscs, mainly represented by the scaphopod *Dentalium,* polychaetes, probably ntirely in the form of *Aphrodite aculeata,* and ophiuroids also appear more frequently than in most of the other reas.

North of Scotland (Table XXXV)

Because of the incidence of the sampling and the difference in depth, the southern half, A16 and ZZ16, is onsidered separately from the northern rectangles, A17, 18 and ZZ17, 18.

Coastal grounds — A16, ZZ16

Sampling was fairly regular over the years 1950–1963 in these rectangles where the depth ranges from 30 to 50 fm and the bottom deposits are predominantly of sand and shells. Unlike many areas in the North Sea the food of both size-groups consists overwhelmingly of fish, and although at least eleven different species are represented 84 % of the smaller cod and 73 % of the larger fish were found to be feeding on sand eels. Moreover this remarkable concentration on one type of food is not confined to one season of the year as the following monthly percentages of cod of all sizes preying on sand eels show.

February	=	90 %	July	=	100 %
March	=	70 %	Aug.—Sep.	=	32 %
May	=	68 %	October	=	46 %
June	=	99 %	November	=	50 %

Although these figures indicate a peak feeding on sand eels in June and July, predation on these fish is also high from February to May. Moreover, although there is evidence of a decline in the frequencies with which

TABLE XXXVI

FOOD OF COD FROM CAPE WRATH TO BUTT OF LEWIS AND NORTH RONA (XX16, XX17, YY16, YY17, YY18)

Years	1928–62				
Months	II–VII, IX–XI				
Length range cm	33–50	51–100			
No. stomachs examined	59	139			
No. empty	8	27			
No. with recognisable food	51	112			
Percentage containing:					
CRUSTACEA	60	31	PISCES	61	73
Decapoda ? spp.	4	3	*Ammodytes*	30	40
Eupaguridae	2	2	*Gadus* sp.	2	3
Portunus	6	3	*G. aeglefinus*	—	2
Hyas	6	4	*G. esmarkii*	—	3
Xantho	—	1	Flatfish sp.	—	2
Galathea	12	3	*Zeugopterus*	—	1
Munida	12	11	*Clupea harengus*	—	1
Crangon	6	—	*Scomber scombrus*	—	1
Pandalus	14	5	*Callionymus*	—	5
Amphipoda	—	1	*Pholis*	2	—
MOLLUSCA	—	4	*Raia* sp.	—	1
Cephalopoda	—	3	*R. naevus*	—	1
Eledone	—	1	POLYCHAETA	4	1
			Aphrodite	2	—

they are eaten in the later half of the year, they are still clearly the most important individual item in the food of cod at this time.

Despite the relatively minor importance of decapods in this area the identification of thirteen different types confirms the extent of cod predation on this group.

Offshore grounds — A17, 18; ZZ17, 18

Sampling on these grounds was much less frequent, and because the cod were mainly over 50 cm in length no distinction has been made between size-groups. *Portunus, Munida* and *Pandalus* were prominent among the crustacean constituents of the food but sand eels, though not so numerous as in stomachs from the adjacent grounds, were clearly the outstanding food type. This has been confirmed by evidence from commercial

ources which suggest that the importance of sand eels as cod food in this area may be even greater than these ecords indicate.

Cape Wrath to Butt of Lewis and North Rona — XX16,17; YY16,17,18 (Table XXXVI)

These grounds are characterised by an even, sandy bottom, 45–60 fm deep. They are not prolific in small od but fish of 51 cm and over are fairly numerous. Fish, again represented very largely by sand eels, occur ore frequently than decapod crustaceans in the stomachs of the cod of both size-groups. As on grounds off he north coast sand eels are chiefly eaten during the summer but some are taken throughout the year. It is nteresting to note the presence of one of the less common Scottish fishes, *Callionymus*, in 5 % of the stomachs f the larger fish.

North Minch — XX14,15; YY14,15 (Table XXXVII)

In the North Minch depths vary considerably and samples of cod were obtained from the shallows of Broad Bay to a depth of 60 fm off the coast of the Scottish mainland. Extensive areas of the sea bottom are

TABLE XXXVII

FOOD OF COD IN THE NORTH MINCH (XX14, XX15, YY14, YY15)

Years	1928–64				
Months	III, V–XI				
Length range cm	29–50	51–108			
No. stomachs examined	58	315			
No. empty	12	38			
No. with recognisable food	46	277			
Percentage containing:					
Crustacea	57	84	Pisces	59	41
Decapoda ? spp.	—	4	*Ammodytes*	15	4
Eupaguridae	—	+	*Gadus* sp.	7	5
Portunus	2	6	*G. aeglefinus*	2	—
Hyas	—	1	*G. esmarkii*	7	5
Atelecyclus	—	2	Flatfish sp.	2	2
Cancer	—	+	*Limanda*	—	1
Inachus	—	+	*Hippoglossoides*	—	+
Geryon	—	+	*Microstomus*	—	+
Nephrops	24	68	*Clupea harengus*	—	2
Galathea	7	3	*Onos cimbrius*	—	2
Munida	7	3	*Callionymus*	4	1
Calocaris	—	1	*Gobius*	4	—
Crangon	—	2	*Merluccius*	2	—
Pandalus	15	8	*Caranx*	—	+
Euphausiacea	—	+	*Scyliorhinus caniculus*	—	+
Isopoda	—	1	*Raia* sp.	—	1
Mollusca	—	3	*R. naevus*	—	+
Cephalopoda	—	2	Polychaeta	—	3
Eledone	—	+	*Aphrodite*	—	3
Rossia	—	+	Ophiuroidea	2	+

vered with mud, although sand occurs in places and some rough ground is located in the vicinity of Cape rath and Scourie Bank, where cod are known to spawn in the early months of the year. Young cod are mparatively scarce on most of the trawling grounds but large and medium-sized fish are plentiful.

The food of the smaller fish consists equally of decapods and fish, while the larger fish, rather surprisingly d in marked contrast to the position elsewhere, eat twice as many decapods as fish. *Nephrops norvegicus* is far the most important individual species eaten by fish of both size-groups — by 24 % of the 21–50 cm cod

and by 68 % of the larger fish. Individual samples have been examined on a monthly basis and the percentages of cod of all sizes feeding on *Nephrops* have been calculated as follows:

March	=	38 %	August	=	74 %
May	=	77 %	Sept.—Oct.	=	50 %
June	=	31 %	November	=	52 %
July	=	95 %			

This shows that cod in the North Minch prey heavily on *Nephrops* at all times of the year. Although the high percentages in July and August suggest a heavier predation during the summer than at other times of the year, this might arise from the incidence of the sampling and would require further investigation for confirmation. Thirteen types of decapod and at least fourteen species of fish are represented in the food, thus indicating a continuation of the extension of the list of organisms preyed upon as one proceeds away from the

TABLE XXXVIII

FOOD OF COD IN WEST OF SCOTLAND—INNER (SKYE TO IRISH COAST)

Years	1928–62				
Months	III–XI				
Length range cm	21–50	51–100			
No. stomachs examined	75	119			
No. empty	9	11			
No. with recognisable food	66	108			
Percentage containing:					
CRUSTACEA	70	74	PISCES	39	34
Decapoda ? spp.	—	4	*Ammodytes*	20	11
Eupaguridae	3	6	*Gadus* sp.	5	2
Portunus	3	2	*G. merlangus*	—	1
Hyas	8	19	*G. esmarkii*	2	1
Gonoplax	2	2	*G. minutus*	—	1
Stenorhynchus	2	1	Flatfish sp.	2	—
Xantho	—	1	*Hippoglossoides*	2	—
Porcellana	2	1	*Clupea harengus*	2	5
Nephrops	11	35	*Callionymus*	—	1
Galathea	6	3	*Onos cimbrius*	—	2
Munida	18	2	*Merluccius*	2	—
Calocaris	2	2	*Agonus*	—	1
Crangon	—	2	*Gobius*	2	—
Pandalus	17	9	*Cottus* (ova)	2	—
MOLLUSCA	2	7	POLYCHAETA	—	13
Lamellibranchiata	—	2	*Aphrodite*	—	6
Modiolus	—	1	OPHIUROIDEA	—	19
Lima	—	1	ANTHOZOA	—	2
Gasteropoda	2	3	HYDROIDEA	—	1
Patella	—	1			
Cephalopoda	—	2			
Loligo	—	1			

North Sea. Next in importance, but a long way behind *Nephrops*, come *Pandalus, Galathea, Munida,* sand eels and *Gadus esmarkii.*

WEST OF SCOTLAND — (1) SKYE TO NORTHERN IRELAND (TABLE XXXVIII)

This area includes the Southern Minch and coastal waters to the east of longitude 7° W from latitude 57° N southwards to the Irish coast. Depths vary considerably and samples of cod were obtained from 20–100 fm. In the Southern Minch mud is prevalent over wide areas, although sand occurs in places. From the Minch

Northern Ireland the situation is reversed, with sand the prevailing bottom deposit and mud in the more eltered localities. Large cod outnumber the smaller fish.

Crustaceans are eaten more frequently than fish by the cod in both size-groups. *Munida, Pandalus, ephrops, Hyas,* and *Galathea* in this order are the main types in the diet of the smaller fish while *Nephrops, yas* and *Pandalus* are the principal food items of the big cod. It should also be noted that *Nephrops* (in 35 % the stomachs) represents the commonest individual species in the food of the larger fish, while sand eels and *lunida* are the leading types in that of the smaller cod. Sand eels, herring and gadoids are the commonest sh eaten by all sizes of cod.

Attention should also be drawn to the relatively high proportions of large cod feeding on brittle stars phiuroids) and polychaetes (probably mainly *Aphrodite*). It must be pointed out, however, that most of

TABLE XXXIX

FOOD OF COD IN WEST OF SCOTLAND—OUTER (WEST OF 7°W)

ears	1928–62				
lonths	III, V–XI				
ength range cm	28–50	51–111			
o. stomachs examined	23	320			
o. empty	8	92			
o. with recognisable food	15	228			
ercentage containing:					
CRUSTACEA	73	54	PISCES	40	62
Decapoda ? spp.	—	8	*Gadus* sp.	7	6
Eupaguridae	—	1	*G. aeglefinus*	—	+
Portunus	20	6	*G. esmarkii*	—	1
Hyas	7	+	*G. minutus*	—	2
Corystes	—	1	*G. poutassou*	—	+
Atelecyclus	7	4	Flatfish sp.	—	2
Gonoplax	7	1	*Microstomus*	—	2
Stenorhynchus	—	+	*Clupea harengus*	—	15
Xantho	—	+	*Scomber scombrus*	—	2
Bathynectes	—	+	*Merluccius*	—	+
Lithodes	—	1	*Callionymus*	—	1
Nephrops	—	14	*Gobius*	—	1
Galathea	13	3	*Pagellus centrodontus*	—	+
Munida	27	19	*Argentina sphyraena*	13	1
Pandalus	—	2	*Urophycis*	—	+
Nika	—	1	*Raia* sp. (egg)	—	+
Euphausiacea	—	+	*Scyliorhinus caniculus*	—	+
MOLLUSCA	7	9	POLYCHAETA	—	1
Lamellibranchiata	7	+	*Aphrodite*	—	+
Chlamys	—	+	OPHIUROIDEA	—	4
Gasteropoda	—	+	SEA BIRD	—	+
Cephalopoda	—	8			
Sepiola	—	+			
Eledone	—	1			

e cod which had eaten ophiuroids were taken in a single sample obtained off the north coast of Ireland in ne 1959. This, together with the knowledge that cod on most grounds rarely prey on ophiuroids and that this pe is commonly eaten by haddock in Scottish waters generally (Ritchie, 1937), suggests that ophiuroids are ten only in the absence of the more favoured types or in the event of cod encountering very heavy brittle star ncentrations.

EST OF SCOTLAND — (2) WEST OF LONGITUDE 7° W (TABLE XXXIX)

The sea bottom in this extensive region consists largely of sand and shells interspersed with areas of rough ound where stones and rocks abound. Patches of mud occur to the south of Barra Head. The area stretches

westward from the Outer Hebrides and longitude 7° W to the edge of the continental slope. Sampling was by trawl and on a few occasions by great-line in depths of 40–100 fm. Young cod of less than 51 cm are very scarce in these deeper offshore waters, apparently because there are no suitable nursery grounds, but large cod are caught over the entire area. The samples also include a few fish from isolated hauls on Rockall Bank and off the west coast of Eire.

The few cod of 21–50 cm were feeding mainly on *Munida, Portunus* and *Galathea*. The large cod, though feeding fairly heavily on decapods, including fifteen different types, among which *Munida* again appears as the

TABLE XL

FOOD OF COD IN THE FIRTH OF CLYDE

Years	1928–1962	
Months	III–V, VII, VIII, X, XI	
Length range cm	21–50	51–100
No. stomachs examined	212	173
No. empty	33	14
No. with recognisable food	179	159
Percentage containing:		
CRUSTACEA	66	86
Decapoda ? spp.	2	1
Eupaguridae	8	6
Portunus	3	4
Hyas	3	1
Atelecyclus	1	—
Gonoplax	—	4
Corystes	—	1
Ebalia	1	—
Carcinus	1	—
Nephrops	33	70
Galathea	3	—
Munida	6	1
Calocaris	—	1
Crangon	3	1
Pandalus	4	1
Hippolyte	1	—
Pasiphaea	—	3
MOLLUSCA	5	2
Lamellibranchiata	2	—
Nucula	1	—
Pecten	1	—
Solen	1	—
Gasteropoda	—	1
Turritella	—	1
Cephalopoda	2	1
Eledone	2	—
PISCES	47	31
Ammodytes	1	2
Gadus sp.	1	1
G. merlangus	—	1
G. aeglefinus	2	—
G. esmarkii	3	6
Flatfish sp.	1	—
Hippoglossoides	2	1
Glyptocephalus	—	1
Clupea harengus	8	3
Onos sp.	—	1
Argentina sphyraena	—	1
Lumpenus	3	1
Callionymus sp.	2	2
Pholis gunnellus	1	—
Gobius	1	—
Cyclopterus	—	1
Salmo trutta	—	1
POLYCHAETA	3	7
Aphrodite	3	7
ANTHOZOA	—	1

outstanding type, feed mainly on fish, of which at least fifteen species were identified in the stomach contents. Of these, herring (in 15 % of the stomachs) represent the outstanding species in the food, while gadoids as a group occur in 10 %.

Two further observations are worthy of note —firstly the rather higher-than-average proportions of the fish feeding on molluscs, the smaller size-group on lamellibranchs (in 7 % of the cod), the larger size-group on cephalopods (8 %), and secondly, the complete absence of sand eels from the stomachs of fish in both size-groups (the only occasion on which this has been recorded in this study of cod food).

'IRTH OF CLYDE (TABLE XL)

Within the Firth of Clyde cod sampling was carried out chiefly at depths of 20 to 40 fm on a sea floor on 'hich mud predominates. The stock consists largely of young fish in the 21–50 cm size group, and a high pro- ortion of those in the larger size-group come within the 51–65 cm range. It is, therefore, not surprising that ecapod crustaceans form the bulk of the food of fish in both size-groups. At least 16 types of decapod and 15 pecies of fish are represented in the food. The outstanding species in the food of cod of all sizes is *Nephrops orvegicus*, which appears in 33 % of the smaller fish and 70 % of the larger fish. A more detailed study of the ecords on a monthly basis reveals the following percentages of cod of all sizes preying on *Nephrops*.

March	= 38 %	May	= 68 %	Oct.—Nov.	= 33 %
April	= 35 %	July	= 66 %		

'hese figures show a higher predation on Nephrops from May to July than at other times and thus indicate a imilar trend to that observed in the North Minch.

Next in importance but a long way behind come hermit crabs, *Portunus*, *Munida*, molluscs (as a group), erring, small gadoids, *Lumpenus* (in the smaller cod) and *Aphrodite*. This suggests a mixed feeding in the Clyde area, a feature which was in some measure confirmed by enquiries in 1957 among fishermen who variously eferred to "prawns", herring, sprats and whiting being seen in the stomachs.

Comparison with previous investigations

Elmhirst (1926) described the food of cod in the inner part of the Firth of Clyde in the early 1920s. lthough the fish examined ranged in size from 25 to 120 cm, it seems likely that most of them would have allen into the lower half of the range. In his analysis, 94 % of the fish were feeding on crustaceans, 22 % on sh, 18 % on molluscs, 15 % on polychaetes and 1 % on ophiuroids. The crustaceans consisted almost en- rely of decapods and included at least 24 different species, among which *Eupagurus*, *Portunus*, *Hyas*, *Galathea*, *Munida*, *Crangon* and *Pandalus* occurred most frequently. The others included *Nephrops* (in only 7 % of the omachs) *Carcinus*, *Xantho*, *Atelecyclus*, *Gonoplax*, *Ebalia*, *Stenorhynchus*, *Inachus* and *Hippolyte*. The com- ionest types in the fish prey were *Callionymus* and herring. Of the molluscs, *Buccinum* appeared in 17 % of ie stomachs and of the polychaetes *Aphrodite aculeata* was found in 5 %.

In general, Elmhirst's results resemble those of the present investigations except in two respects —) the much smaller proportion of the cod feeding on *Nephrops* and (2) the fairly high proportion eating *uccinum*. These differences, however, may be explained by the local origin of the fish examined by Elmhirst. or example, it is evident from the investigations of 1951–1962 that *Nephrops* is not so common in the vicinity the Cumbraes where many of Elmhirst's samples were obtained. Further, all the cod feeding on *Buccinum* ere procured from one position to the south-west of the Island of Bute. This feature of heavy, local predation y cod on individual molluscs has already been noted in these studies.

In general, the food in the Clyde sea area resembles that of cod in the Irish Sea (Johnstone *et al*, 1924).

CONSIDERATION OF RESULTS

These studies demonstrate a number of features in the food of cod in Scottish waters. The most obvious these is the preponderance of decapod crustaceans and fish in the diet of all sizes over 21 cm and the relative importance of other food groups. Combining all the records in Tables VI to XL, 62 % of the cod in the –50 cm size-group were feeding on crustaceans and 54 % on fish, and 50 % of the cod of 51 cm and over ere feeding on crustaceans and 66 % on fish. It has already been pointed out that, owing to the general milarity in the size of the various food items, the percentages giving the frequency of occurrence of these ems in the stomachs may also be regarded as reasonably representative of their volumes.

Of the other animal groups preyed upon, the molluscs and polychaetes are the most important, but even gether these are of minor importance compared with decapod crustaceans and fish as regards their frequency occurrence in the stomachs. Each of the various food groups is worthy of further consideration.

The Role of Crustaceans in the Food of Cod

Few cod below 21 cm in length were examined, but these (see Tables VI and XIII) indicate the overall importance of crustaceans to the fish in this size-group. It is also evident that the crustaceans eaten by the smallest cod include numerous small organisms, such as the smaller and younger forms of decapods (particularly natant types like crangonids and pandalids), euphausiids, mysids, amphipods, and isopods. Smith (1890) examined 33 juvenile cod of 5–8 cm from the Moray Firth and found the food to be mainly copepods and amphipods; the ostracod stage of *Balanus* was found in two stomachs, young decapods in two, young gasteropods in one, larval ascidians in three and fish remains in two. Todd (1907) found the food of cod of less than 15 cm to consist wholly of crustaceans. These records are in reasonably close agreement with the comprehensive studies of the food of the smallest cod in Danish waters (Poulsen, 1931) and in Norwegian waters (Wiborg, 1948). Similar results were obtained by Naumov (1958) in the Baltic Sea and by Powles (1958) in the Gulf of St Lawrence.

Although some of the smaller cod of the 21–50 cm size-group also prey on euphausiids, amphipods, mysids etc. these types are of negligible importance to fish of this size, which, in general, prey predominantly on the smaller and younger decapod crustaceans, both natant and reptant. Little effort has been made to identify the various species as this would have proved too time-consuming in the circumstances in which this work was done, but the variety of decapods eaten by cod is apparent from the relatively large number of genera recognised. Some of these types, for example *Eupagurus, Portunus, Hyas, Galathea, Crangon* and *Pandalus*, are eaten regularly and sometimes in considerable quantity on nearly all the grounds investigated, while others are eaten on more restricted grounds where physical and ecological conditions favour their existence. The most prominent example of the latter is the predation on the Norway lobster, *Nephrops norvegicus*. A native of muddy bottoms, this animal is eaten by cod only in those areas which include conditions suitable for its survival (Fig. 3). In such areas it sometimes forms, expecially to the bigger fish, the outstanding constituent of the food, as for example in the Minches and in the Firth of Clyde. Other types exhibiting a somewhat local importance in the food of cod include *Cancer pagurus* and *Carcinus maenas* in coastal and estuarine waters, *Corystes cassivelaunus* on rather shallow, sandy bottoms, *Geryon tridens* in the deeper parts of the northern North Sea, and *Munida* in the deeper waters off the west of Scotland and to the west of Shetland and Orkney (see Appendix).

The transition from the relatively shallow southern North Sea to the deeper parts of the northern North Sea and west coast grounds is marked by a gradual increase in the number of decapod types eaten by the cod. In addition to *Geryon* and *Munida*, certain less important types such as *Gonoplax, Xantho* and *Lithodes* begin to appear in the stomachs, and the fairly widespread type *Atelecyclus* occurs more frequently as one proceeds northwards.

Despite the numbers of eupagurids eaten by cod of all sizes, the shells inhabited by these animals are rarely found in the stomachs. This suggests either that the hermit crabs are eaten while transferring from one shell to another or that the cod are able to extract the animals from their shells.

The Role of Fish in the Food of Cod

Fish are seldom eaten by cod of less than 21 cm and those which do appear in the food are generally post-larval or juvenile types. Very young fish continue to be eaten by cod of 21–50 cm but mainly by those in the lower half of the range, and in general an increase in the size of the cod is accompanied by an increase in the average size of the fish they eat — a feature similar to that already noted in discussing the crustacean constituents of the food.

The food of cod in most areas is marked by a gradual change-over from decapod crustaceans to fish as the cod grow. The fish eaten by cod include a large number of species and range from post-larval to adult forms. This, as in the crustaceans, is partly explained by the species preyed upon varying according to the ecological conditions frequented by the cod. Thus in the Firth of Forth and in Inverness Firth the cod commonly feed on typical estuarine species, including *Lumpenus, Pholis, Cottus* (more frequently on their spawn than on the fish themselves), *Gobius, Zoarces, Syngnathus* (pipe-fish), *Spinachia* (15-spined stickleback), as well as on the young of herring, sprat and other types of economic importance.

Throughout the relatively shallow southern North Sea, flatfishes, including young or small forms of the Soleidae, were the most prominent of the fish types in these studies of the food, but it is evident from the

ıdividual samples that sand eels are the outstanding item in the food in certain localities. Further north, in eeper water, shallow-water forms, like *Solea,* are absent from the diet but the number of different species eaten ıcreases and includes growing proportions of small and young gadoids.

It is also interesting to note an increase in the proportion of fish eaten by cod of all sizes in the Central lorth Sea as one proceeds eastwards from the Aberdeenshire coast to the Great Fisher Bank. On this transect, hiting, Norway pout, herring and mackerel were the outstanding species in the diet of cod, but seasonally the elagic types, herring and mackerel, dominated all other individual species.

Throughout the Moray Firth sand eels are of supreme importance in the food of cod of all sizes — an bservation which has been confirmed by replies to an enquiry addressed to fishermen in the area. Herring are rominent in the diet of the smaller cod. Sand eels are also the outstanding food of cod on East Orkney rounds and in the Foula-Scalloway Deep area, and finally reach a remarkable predominance off the north-oast of Scotland where they are eaten by 70–85 % of the cod of all sizes over the entire year.

In these areas and also within the Cape Wrath-Butt of Lewis-North Rona triangle it would appear that the bnormally high predation on sand eels by cod follows directly on very dense concentrations of these pelagic or emi-pelagic fish, expecially during the summer. Since it is evident from the stomach contents of the cod and f other species of fish, that other food types normally eaten by cod are also present on these grounds in some uantity, it may be that cod show some preference for sand eels in this area. As the genus *Ammodytes* is eaten y cod over almost the entire area covered by these investigations, and because of the high frequency with hich it is taken in some areas, it must be regarded on an average as the most important food type to all xcept the smallest cod in the north-western North Sea and west of Scotland grounds (Fig. 4).

In addition to sand eels, three group types, gadoids, clupeoids and flatfishes, play important parts in the od of cod, particularly of the larger fish. Six species of gadoids were identified during the analyses and of these ıe whiting appeared most frequently in the stomachs, no doubt in consequence of its overall abundance and s wide distribution over the area investigated. Haddock were also commonly eaten over a wide area, but the orway pout (*Gadus esmarkii*), as its distribution in the deeper water areas would indicate, tended to be eavily preyed upon only in certain areas, especially in the northern North Sea and off the west of Shetland. *adus poutassou* and *G. minutus* were eaten much less frequently and young cod were taken only on rare occa-ons. The complete absence of two species of gadoid, saithe or coalfish (*Gadus virens*) and pollack or lythe (*G. ollachius*) is, however, surprising. The occurrence of gadoids in the food is indicated in the Appendix.

The clupeoids were represented in the food by only two species, the herring and the sprat, but the former ust be regarded as one of the most important food types. As indicated while discussing the food in the various gions, herring not infrequently proved to be the cod's commonest prey at certain seasons. This was particu-rly noticeable on some traditional herring drift-net grounds during the summer, and to some extent also coastal or estuarial waters during the winter months when young herring and occasionally sprats were the ief attraction. The records of herring having been eaten by cod include a small number in which the fish early had eaten herring spawn, sometimes along with and sometimes without the parent fish. The most markable example of this was recorded from north, west and south-west of St Kilda and from west of rra Head in March 1959 and from south-west of St Kilda in March 1962.

At least ten species of flatfish were identified in the stomach contents. The presence of these fish in the od reflects their natural distribution throughout the North Sea. Thus *Solea,* including *Solea lutea* (solenette), ıs eaten by cod in the southern North Sea and on a few occasions in the inner Moray Firth; plaice were taken rare occasions in shallow sandy bays, flounders in estuarial waters, witches on muddy grounds and megrim the deeper waters of the northern North Sea. Lemon soles were eaten more frequently than those already entioned but the two most important flatfishes in the cod food were common dab and long rough dab (see ppendix).

Nearly 60 different species of fish are named in the Appendix as identified in this analysis of the food of d. This undoubtedly reflects the importance of fish in the cod's diet and also the ability of this fish to find od under different ecological conditions. This is perhaps demonstrated most clearly by the numbers and riety of fish of little or no economic importance appearing on the list of food items. Of these, four species noteworthy — *Agonus cataphractus,* mainly in sandy bays, *Lumpenus lampetraeformis,* particularly on the ddy grounds of the Firth of Forth, *Callionymus lyra,* eaten regularly over a very wide area, and *Argentina ıyraena,* a typical food of the deeper waters of the northern North Sea and western grounds.

Do cod eat smolts?

The fate of large numbers of the salmon smolts which yearly leave Scottish rivers has long been a source of speculation, since it is known that relatively few survive to return as adult salmon. It is obvious that the smolts must suffer a considerable natural mortality in the sea and various theories have been advanced in explanation. Calderwood (1907) states that smolts occurring in great numbers off the mouths of Scottish rivers, in May and June, at times fall an easy prey to coal-fish (or saithe — *Gadus virens*) and other members of the cod family. There is certainly evidence that saithe prey on smolts at the mouths of certain rivers, notably the Spey, but only in certain years. Piggins (1959) found pollack (*Gadus pollachius*) and an occasional coal-fish feeding on smolts in Lough Furnace, Eire, from the beginning of April to the beginning of June 1958. Gudjonsson (1953) records the recovery of one smolt, out of a total of 182 tagged in the River Ulfarsa in Iceland, from the stomach of a cod caught 5 km along the coast from the river estuary.

From 1954 to 1958 over a thousand cod were caught by handline close to the mouth of the River Dee at Aberdeen from the end of March to the end of May, thus covering the main smolt run. These cod were feeding when caught but no trace of salmonid smolts was discovered in their stomach contents. Moreover, with the exception of a single record of sea trout remains found in a cod caught in the Inner Firth of Clyde in July 1954 (see Table XL), no trace of salmonid remains has been found in the 15,000 cod stomachs examined during the investigations described in this paper.

In this connection, however, it is interesting to refer to a few experiences reported by fishermen in recent years:

1. The Skipper of the Aberdeen trawler "George R. Wood" reported the finding of a salmonid, 14 to 16 inches long, in the stomach of a large cod caught 8–9 miles ESE of Aberdeen on the night of 18th–19th February 1964.

2. Skipper G. McKay of the m.v. "Fidelis" of Macduff found an unusual fish in the stomach of a cod in the Moray Firth off Troup Head on 14th May 1964. The fish, 15·4 cm long, was identified by the Department's staff as a salmon smolt of 3 years of age.

3. In May 1965, Skipper J. Paterson of the m.v. "Maureen" of Eyemouth caught a large cod which had eaten a salmonid of 18 inches (45·7 cm).

4. On 28th July 1965, Skipper McKay of the "Fidelis" caught another cod, also off Troup Head, which had eaten a young sea trout of just over 2 years of age.

5. On 4th March 1966, Skipper McLeod of the "Muiranna" found a sea trout in the stomach of a cod of 27 inches taken in Donegal Bay, Eire.

It is evident from these records that cod may occasionally feed on salmon and sea trout, but the scarcity of the records and the fact that the fishermen concerned found them sufficiently unusual to be worth bringing them to our notice is additional proof that cod do not prey heavily on smolts or older salmonids.

The Role of other Group Types in the Food of Cod

It has already been shown that the food of cod of 21 cm and over in Scottish waters consists predominantly of decapod crustaceans and fish (see page 50). Only brief references need, therefore, be made to the remaining group types.

Molluscs

Overall, 2·7 % of the smaller cod and 4·4 % of the larger fish were found to be eating molluscs. These included all the main classes in this phylum — lamellibranchs, gasteropods, cephalopods and scaphopods. As already mentioned in dealing with the various localities and areas, cod predation on molluscs, though fairly widespread on nearly all the grounds examined, tends, in some respects, to be both specific and local. Thus, in Aberdeen Bay, 15 % of the larger cod were preying on molluscs, including 11 % on the lamellibranch *Ensis*; in the Great Fisher Bank area of 9 % feeding on molluscs, 8 % had eaten gasteropods, probably *Buccinum*; and of 16 % feeding on molluscs off north-west Shetland, 14 % had eaten the small scaphopod *Dentalium*.

Although the smaller molluscs are generally eaten complete with their shells, little evidence was found in the cod stomachs of the ingestion of the shells of the larger types such as *Buccinum* and *Ensis*. These observations seem to indicate the ability of cod to extract the flesh of these animals from their shells.

Polychaetes

On average, polychaete worms were found in the stomachs of almost 2·5 % of the smaller cod and in 5 % of the larger fish. The remarkable feature of cod predation on this group, however, is the extent of its concentration on one species, *Aphrodite aculeata*, which was taken over a wide area by 4 % of the larger cod (see Appendix). In certain areas up to 15 % of the cod of 51 cm and over were eating this animal, which no doubt would be attractive to cod predators owing to its sizeable and compact form.

Echinoderms

Although four sub-groups of this phylum were identified in the cod food, three of them, holothurians, echinoids and asteroids, occurred only on rare occasions and ophiuroids (brittlestars) alone appeared in the stomachs with any regularity. These were present in 0·5 % of the cod of 21–50 cm and in 1·7 % of the larger fish. On some grounds ophiuroids appeared not to be eaten by cod, but on others they were taken by anything up to 4 % of the larger fish. An outstanding exception to this is recorded from one region on the west of Scotland where 20 % of the fish were found to be feeding on ophiuroids. This result was mainly obtained from one haul in June 1959 off the north coast of Ireland, in which 21 out of 26 cod (range 27–76 cm) contain ophiuroids, which were represented by two species, *Ophiopholis aculeata* and *Ophiothrix fragilis*. This concentration on ophiuroids is unique in these investigations on Scottish grounds but Smith (1889) records the presence of echinoderms in eleven out of 28 cod stomachs examined from an unspecified position on the west of Scotland. Ophiuroids are a regular feature of the food of cod in certain localities at Faroe (Rae, unpublished), and Brown and Cheng (1946) found them frequently in cod stomachs from Iceland, Bear Island and Spitzbergen in the summers of 1936 and 1937.

It has already been suggested (page 47) that the cod may have taken the ophiuroids on this occasion because of a scarcity of other more favoured types or because of an abnormal concentration of the animals on the sea floor. Whatever the cause may have been, it is perhaps worth noting that only four of the cod were feeding on fish, including two on post-larval types, and although 25 had been feeding somewhat sparsely on decapod crustaceans the food also included a variety of molluscs, polychaetes and coelenterates. This variety and the scarcity of fish may indicate a scarcity of the cod's normal food but on the other hand the concentration on ophiuroids may possibly be explained by some behavioural feature in the cod.

Minor food types

The contents of the cod stomachs also included ascidians, gephyreans, nemerteans, anthozoans, hydroids, ctenophores and algae, but these types appeared on so few occasions that their combined effect can only be regarded as negligible.

Perhaps the most interesting of these miscellaneous types are the ctenephores. Represented by the single genus *Beroe*, these organisms were recorded on three occasions, all obtained at or near the entrance to the Firth of Forth, where Smith (1891) also found them in a cod stomach. Fraser (1960) has recorded cod feeding on calps to the west of Orkney in September 1958. These records, together with the somewhat rare occurrence of euphausiids in the stomach contents, reveal the limited predation by cod over 21 cm in length on planktonic organisms in Scottish waters. In this respect the food of cod around Scotland differs quite markedly from that of the Arctic, where ctenophores and other planktonic types have frequently been recorded in the stomachs.

Many curious items, both animate and inanimate, have been found by fishermen and fish workers in the stomachs of cod. These discoveries have helped to stress the general view that the fish is omnivorous in character, but the present studies suggest that this is only true within the limits of decapod crustaceans and fish. Offal discarded from fishing vessels was identified by Stanek (1964) in the stomachs of 90 % of feeding cod in one locality of the north-western Atlantic, but it was concluded that such items were eaten only occasionally. The present investigations in Scottish waters have produced no reliable evidence of the occurrence of offal in the stomachs but simultaneous observations on Scottish research vessels at Iceland have revealed cod feeding on the severed heads and guts of herring on one occasion.

Perhaps the most unusual item identified in the present food analysis was the sea bird taken from a large cod caught on Porcupine Bank to the west of Eire. Birds, however, have already been recovered from cod stomachs on a number of occasions. Brook (1886) identified a guillemot from a cod caught in the Moray Firth and a small land bird, probably a meadow pipit, from a cod taken off Berwick, and Iversen (1936) found the feathers of sea-birds in cod stomachs from Jan Mayen on two occasions.

Finally, reference must be made to the occurrence, from time to time, of smooth pebbles, including sea-rounded pieces of coal, in the stomachs of cod. Similar observations have been recorded by other workers in regard to cod and other species.

Feeding Habits

The contents of individual cod stomachs vary greatly; this may be partly owing to the fullness of the stomachs, but even a small quantity of food may include the remains of several decapods and/or fishes and other animals, while full stomachs may contain both traces of some organisms and other items of food at various stages of digestion. It is, therefore, often difficult to determine the exact number of organisms present in the stomachs. For this reason and the fact that certain resistant parts, crab claws, cephalopod jaws and otoliths, may be retained for some time after the digestion of the softer parts, counts of the various animals found in the stomachs are not regarded as reliable indices of their quantitative importance.

The numbers of different items in the stomachs also depend to some extent on the size of the individual animals eaten — in general the smaller items in the food are eaten more frequently by individual fish than the larger units. Although, for example, 60 specimens of *Munida* have been found in a cod of moderate size, and as many as 12 adult herring have been taken from a single large cod, such experiences are on the whole exceptional and the average numbers of organisms in the stomachs are usually much smaller.

It is appropriate at this point to refer to the manner in which pelagic fish are sometimes taken by cod. On different occasions, when herring, mackerel and sand eels were eaten, the fish appeared to be swallowed tail first which suggests that the cod pursued their prey.

The intensity of feeding by cod throughout the year has already been considered (page 9). This has shown that the cod, like other gadoids (Ritchie, 1937; Jones 1954; Raitt and Adams, 1965) continues to feed, though with variable intensity, at all seasons, and that in this respect it differs from certain flatfishes, found on the same grounds, which reveal a marked decline in feeding intensity during the winter. The most remarkable of these is the lemon sole, in which feeding stops almost entirely from the end of November until January and thereafter increases gradually to a maximum intensity during the late spring and summer (Rae, 1956). The intensity of feeding of cod, however, judging from the proportions of full and empty stomachs, does fluctuate throughout the year. For example, feeding would appear to be intense in January and February, but falls off in March and April, the main spawning period in Scottish waters. In May, intensive feeding is resumed and apparently reaches a peak in June, after which it tends to decline, though continuing to fluctuate somewhat till the end of the year.

Seasonal changes in the food

While considering the food in the various localities and regions, attention has been drawn to evidence of seasonal changes in the various food types. In order to demonstrate this effectively sampling must be carried out regularly throughout a number of years. This condition is reasonably well satisfied by records from the Firth of Forth which seem to indicate certain seasonal changes in the food of cod (see Fig. 2). Among the decapods, *Nephrops* appears to reach its greatest importance from March to June and to be of least value to the cod from July to October and again in January and February. *Crangon* is eaten most frequently from October to March and less so from April to August, while predation on *Pandalus* presents a somewhat similar pattern throughout the year. Among the fish, the outstanding species in this area, *Lumpenus*, is taken mainly from April to June, and the clupeoids, small herring and sprats, chiefly from December to April, at a time when these fish are in sufficient concentration to support a commercial fishery. Sand eels attain their peak of importance in June and July and flatfishes apparently from October to April.

Herring are eaten by cod throughout almost the entire North Sea (see Appendix). Young fish for man appreciable part of the food of codling in the Firth of Forth and in the inner Moray Firth during the winter months, while adult shoals are preyed upon from May to September on grounds east of the Aberdeenshire

coast and at a number of localities in the northern North Sea. Mackerel would also appear to be a summer-time food of cod, particularly in the central North Sea from 57° latitude northwards to 61°30′ N. Sprats on the other hand are eaten mainly during the winter and early spring in the Firth of Forth, the Moray Firth and on the Aberdeenshire coast, at the time when the stocks of these small fish are being exploited by fishermen.

Sand eels are eaten at all times of the year in the Scottish area but, as has been shown while considering the various localities and regions, these fish are predominantly a summer food of the cod, reaching remarkable proportions on grounds adjacent to the north coast of Scotland. Moreover, as will be shown later, while considering observations on the food of cod submitted by fishermen, dense shoals of sand eels frequently appear on certain North Sea grounds, for example from north-east to south-east of the Aberdeenshire coast in May and June where they form an attraction to concentrations of cod. These results, together with the absence of sand eels from the stomachs of cod taken in deeper water to the west of 7° W longitude seem to confirm earlier observations by Henderson (1961) of the predominant distribution of sand eels in coastal and shallow waters.

So far evidence of seasonal predation on fish has mainly been concerned with pelagic species. A slight seasonal predation on white-fish has been observed in the Firth of Forth and in Aberdeen Bay, where whiting are eaten during their annual inshore movement at the end of the year. Evidence of seasonal predation on white or demersal fish is, however, not nearly so obvious as it is on pelagic types.

In certain areas decapod crustaceans are the predominant food of cod. In some localities this is largely because of the smaller average size of the fish, but in others the nature of the sea bottom and the animal communities are the determining factors. The food in the Firth of Forth and in the area adjoining the Aberdeenshire coast is mixed, and includes a wide range of decapods. Although some slight evidence of a seasonal variation has been noted in the Firth of Forth, this is not conclusive. In the Minches and in the Firth of Clyde decapods are also of supreme importance but in these areas one species, *Nephrops norvegicus,* outnumbers all other types in the food. In each of these areas there is some evidence that cod prey more heavily on *Nephrops* during the summer months.

In dealing with the Firth of Forth it was pointed out (page 20) that the variations in the food of cod are not equally apparent every year, and may be influenced by a number of factors, including the natural fluctuations in the yearly survival and distribution of the food types themselves and in the strength and distribution of the various year-classes of cod. Feeding habits are also likely to be affected by the appearance or non-appearance on any grounds of the highly mobile and seasonal species such as sand eels, herring, sprat, mackerel and whiting, whereas the less mobile decapod crustaceans are likely to be more or less equally available over the whole year, apart from natural fluctuations in the annual recruitment to their local stocks. It is evident, therefore, that seasonal differences in the food are more apparent in those areas where pelagic fish are the principal prey than in areas where the food consists mainly of demersal types and decapod crustaceans.

The cause of shoaling in cod

Fishing for cod in Scottish waters is often characterised by heavy "bags" of fish by some vessels, while others in the immediate neighbourhood make light or even blank hauls. This is regarded as reflecting the "patchy" nature of the distribution of this fish in the Scottish area — a feature which would appear to be evident during the spawning period but even more so during the subsequent period of intensive feeding in May and June. It has been assumed, therefore, that these concentrations of cod are for the purpose of spawning or feeding.

Graham (1924) in his study of the North Sea cod attempted "to correlate the percentage of the determining food with the concentration of the cod expressed by the catch per 100 hours' fishing for each voyage." This was found to be difficult and no very obvious correlation was observed between catch and any of the commoner food types, with the exception of herring. Graham concluded "if, as is very probable, this is a feeding movement, its occurrence is probably connected directly with the annual occurrence of herring in the area; but other food species, such as *Geryon tridens, Nephrops norvegicus, Aphrodite aculeata* and the haddock, as well as herring, may cause local concentrations."

In order to investigate the reason for the concentrations in Scottish waters, skippers and mates of vessels vessels landing catches of cod at Aberdeen were questioned about the stomach contents of the fish. The results of this enquiry, extending from 23rd May 1957 to 11th June 1958, are reproduced in Table XLI. Although most of the enquiries were made from March to June some results were also recorded at other times. Most of

TABLE XLI

CATCHES OF COD AND CODLING LANDED AT ABERDEEN MAY 1957—JUNE 1958 WITH NOTES ON THE COMMONEST FOOD IN THE STOMACHS AS OBSERVED BY THE FISHERMEN

Year	Month	Vessel	Grounds	Wt in cwt	Principal food observed
1957	23 May	Dulcibelle	Whiten Head Bank	113	Sand eels up to 12″ long
	,,	John Morrice	Buchan Ness	9	Sand eels
	,,	Filey	Turbot Bank	79	Sand eels
	,,	V. Freedom	15′ NE Rattray Head	91	Sand eels
	30 May	River Dee	60′ E Aberdeen	220	Heavily on sand eels inc. up to 12″ long
	,,	Soubrette	65′ E Aberdeen	119	Heavily on sand eels inc. large size, cod being caught mainly during day
	1 June	Bervie Braes	Turbot Bank	57	Sand eels
	5 ,,	Strathalva	Turbot Bank	95	Heavily on sand eels, inc. large size, codling on smaller sand eels
	,,	Wilronwood	Turbot Bank	93	Sand eels
	,,	Curlew	Turbot Bank	33	Sand eels, haddock and whiting
	6 ,,	Loch Hourn	Turbot Bank	174	Heavily on sand eels
	11 ,,	Viking Deeps	30′ ExN Aberdeen	233	Sand eels
	13 ,,	Loch Hourn	64′ E Aberdeen	183	Sand eels
	17 ,,	Strathdee	65′—70′ E Aberdeen	227	Sand eels
	26 ,,	River Esk	Turbot Bank	93	Sand eels
	29 ,,	SN Southern Cross	40′ ExN Aberdeen	40	Herring and prawns (? *Nephrops*)
	31 July	Curlew	Wee Bankie	27	White fish (gadoids and flat-fishes)
	26 Sept.	Emma Wood	5′ NE Rattray Head	163	Sand eels
	13 Nov.	Clovella	Nun Bank	294	Cod not feeding
	2 Dec.	?	Noup Deep	?	"Whitebait" (probably *Gadus esmarkii*)
	10 ,,	(Cod-nets)	Kincardine coast	(few)	Whiting
1958					
	4 Feb.	(Seine)	North of Scotland	?	"Mixed feeding" (crustaceans, fish, etc.)
	14 Mar.	Dunnottar	14′ E Wee Bankie	?	Large herring
	15 ,,	Lotus	40′ NW Butt of Lewis	183	Heavily on large herring
	,,	Ythan Braes	30′ NW Ronas Voe	43	Large herring
	,,	John Morrice	65′ ExS Aberdeen	20	"Mixed feeding"
	19 ,,	P. Nutten	60′ ExS Aberdeen	81	Small herring (finger-length fish)
	,,	P. Fannon	60′ ExS Aberdeen	59	Sprats (finger-length fish)
	,,	Westholme	70′ ExS Aberdeen	61	Sprats and herring (finger-length fish)
	,,	Braconbrae	60′ ExS Aberdeen	85	Sprats and herring (finger-length fish)
	,,	Dunnottar	60′ E Aberdeen	150	Small squids
	20 ,,	John Morrice	65′ ExS Aberdeen	130	Some feeding on small squids, others empty
	,,	Narcissus	60′ ExS Aberdeen	131	Herring and small squids
	21 ,,	Woods	65′ ExS Aberdeen	62	Herring but no squid
1958	21 Mar.	Tritelia	57′ ExS Aberdeen	14	Small dabs in some but little feeding
	,,	Avondee	65′—70′ ExS Aberdeen	50	A few herring and small crabs
	,,	Bempton	45′ E½S Aberdeen	23	Sand eels
	22 ,,	Geo. Hastie	60′ E Aberdeen	35	Haddock and whiting (no herring, sand eels)
	,,	Strathalva	65′ E to ExS Aberdeen	57	Small herring, sprats, small squids
	29 ,,	Braconbrae	70′ E Aberdeen	43	Little food in stomach, cod ripe and running
	11 Apr.	John Morrice	65′ ExS Aberdeen	34	Sand eels
	17 ,,	Ythan Braes	40′ NExN Flugga	67	Large herring

TABLE XLI (*continued*)

Year	Month	Vessel	Grounds	Wt in cwt	Principal food observed
	17 Apr.	Schiehallion	14′—18′ NE Buchan Ness	40	Sand eels
	18 „	Silver Chord (liner)	190′ ENE Aberdeen	?	No food in stomachs
	25 „	V. Prestige	70′ E Aberdeen	?	Sand eels
	„	J. S. Melville	55′ E Aberdeen	?	Sand eels
	„	(hand lines)	2′ E Buchan Ness	?	Mainly sand eels, crabs
	3 May	Floriage (seine)	4′—5′ off Scurdy Ness	few	Razor shells (*Ensis*)
	7 „	V. Freedom	25′ NE Buchan Ness	112	Heavily on sand eels
	15 „	Various trawlers	16′—20′ NE Buchan Ness	?	Sand eels
	22 „	Ythan Braes	26′ N to NNW Cape Wrath	207	Heavily on sand eels with few herring
	23 „	Geo. Craig	6′ SE Buchan Ness	68	Sand eels
	27 „	Geo. Craig	6′ SE Buchan Ness	30	Heavily on big sand eels
	„	Cadorna	Sule Skerry	108	Small sand eels
	„	V. Monarch	Viking Bank	85	Herring and mackerel
	28 „	Emma Wood	Rattray Head	114	Sand eels
	„	Morven	20′ NE Buchan Ness	212	Sand eels
	„	Wilronwood	36′ E Buchan Ness	63	Sand eels
	„	?	Aberdeen Bank	?	Sand eels
	4 June	Ythan Braes	35′ NW Cape Wrath	?	Sand eels
	11 „	?	38′ ENE Aberdeen	?	Sand eels
	„	Geo. Craig	Aberdeen Bank	?	Small white fish, inc. lemon soles, and herring

ıe catches were by trawlers fishing for two to three days on grounds adjacent to the east coast of Scotland so ıat the catches from these grounds are roughly comparable. The range in size of the individual catches of ɔd is remarkable, thus indicating the patchy distribution of the species. This obviously indicates a tendency ɔ congregate in dense shoals. An analysis of the food notes by the fishermen shows that sand eels were recorded . 34 of the 62 catches, including 12 of the 18 major catches of 100 cwt and over. Moreover, in eight catches in hich the fish were reportd as feeding heavily, seven were eating sand eels and one herring. These records early help to confirm the conclusion reached earlier in this paper that sandeels represent the outstanding od of cod in Scottish waters. Next in importance to sand eels in these commercial catches, come herring, hich were recorded in 15 of the 62 catches and were recognised as the chief food in three of the heavy catches over 100 cwt. Among the other types, haddock were identified as the predominant food of the cod in two tches, whiting in three, other gadoids in two, flatfishes (dabs and lemon soles) in three, sprats in four, mackerel one, crabs in three, prawns in one, squid in four, and razor shell in one, while in five catches variable but ɔpreciable numbers of the cod were not feeding. All of these types are normal constituents of the food of ɔd, although the four occasions on which squid formed a prominent part of the stomach contents are without ecedent in the material collected from research vessels. Furthermore, all four instances of cod feeding on ıall squid were recorded in March at a time when these organisms are generally inconspicuous in Scottish ıters. In the circumstances, these reports of squid forming the chief food of large bodies of cod must be cepted with caution.

The outstanding feature of these records by fishermen, apart from the predominance of sand eels, and in me degree of herring, is the overwhelming importance of pelagic or semi-pelagic species generally. Thus nd eels, herring, sprats, mackerel and squid were conspicuous in the food of 51 of the 62 cod catches, whereas mersal fish and benthic invertebrates were prominent in only 11. This suggests a pelagic or near-pelagic eding habit in the cod on a scale even greater than that suggested by most of the data from research vessels; is difference, however, may arise from the commercial sampling being carried out chiefly from March to ne when sand eels and herring normally are more abundant on the grounds. A number of big catches of cod

have been taken by research vessels and these have certainly emphasised the importance of sand eels, but in general sampling has been widespread and has not concentrated on areas where cod congregate. While the research records demonstrate the overall importance of sand eels they also emphasise the importance of demersal fish and benthos in the food of cod.

It would appear, therefore, that cod are attracted into shoals while in pursuit of shoaling pelagic species, especially sand eels and herring. This does not necessarily mean that the cod always rise into the upper water layers because, if this were so, it is unlikely that catches would be as great as they are. It is possible, however, that pelagic or semi-pelagic species are preyed on by cod just above the sea bottom, but still below the headline of trawls and seines. Moreover the diurnal vertical movements of pelagic fishes could well bring them within the range of cod feeding on or near the sea bottom.

Do cod feed while spawning?

Fishermen have long maintained that spawning fish do not take food. In order to obtain information on this subject Moray Firth fishermen, who annually fish the spawning cod shoals on local grounds, were questioned by Mr A. Noble, while he was serving as Fishery Officer at Wick in 1957. The general feeling among the fishermen in that port was that although cod continue to feed while the milt and roe are in their final stages of maturation they do not take food during the actual spawning process. At this stage the fish are regarded as being "sick" and "too lazy to take avoiding action" on the approach of a net, hence one explanation for the big catches frequently secured during the spawning season.

A catch landed by an Aberdeen trawler from 70 miles east of Aberdeen on 29th March, 1958, included three scores of large cod in the ripe and running condition. These fish had a little food in their stomachs (Table XLI). On 15th April of the same year a tagged female cod, in ripe and running condition, was recaptured 14 miles ESE of the Isle of May with its stomach a quarter full of decapod crustaceans, including *Portunus* and *Pandalus*.

From observations on research vessels the proportions of cod with empty stomachs indicate an overall decline in the intensity of feeding during the spawning period. Although nearly 3,000 cod were examined from the beginning of February to the end of April (covering the main spawning period), and these included appreciable numbers of ripe cod, surprisingly few of the fish were in the ripe and running condition. Unfortunately, too, the condition of the reproductive organs was not always recorded when the stomach contents were being examined. In March 1957, however, the author personally examined large cod caught by F.R.S. *Explorer* in the central North Sea. Many of these fish (length range 74–110 cm) had already spawned and were feeding heavily, mostly on mackerel and herring, but also on whiting, flatfishes and a variety of decapod crustaceans. Four of these fish, however, caught in rectangle E13, were taken while spawning and were recorded as follows:

1. female, 81 cm, ripe and running — feeding on *Eupagurus* and flatfish;
2. female, 91 cm, ripe and running — feeding on 2 mackerel;
3. male, 79 cm, ripe and running — feeding on 1 whiting, 1 *Aphrodite*, 1 *Eupagurus*;
4. female, 106 cm, ripe and running — stomach empty.

The contents of the stomachs were easily recognised, thus indicating their recent ingestion. If, as seems probable, however, food may be retained in the stomachs of fish for some considerable time after ingestion, then the stomach contents of the first three specimens could have been taken in their last meal immediately prior to the commencement of spawning. Referring to the feeding and food of cod in the southern Baltic, Strzyzewska (1959) writes — "During the spawning period the cod feeds less intensively, however, the running fish (stage VI) have their stomachs full of food. As a rule the amount of food taken during the spawning period is two to three times smaller than during the feeding period." This statement if anything seems to complicate the problem still further.

Although the evidence is somewhat inconsistent, it would appear that in Scottish waters at least cod, while spawning, tend to take less food than usual and may even stop feeding completely for a time. It is clear, however, that the stoppage of feeding, if it occurs, is of relatively short duration, since ripe, spawning and

pent cod from the same grounds and at the same time have all been found with appreciable quantities of dentifiable food of similar types in their stomachs.

COMPARISON WITH THE FOOD OF COD IN OTHER REGIONS

It has been shown that the food of cod in the North Sea and on west of Scotland grounds consists predominantly of decapod crustaceans and fish, the proportions varying according to the size of the cod and the cology of the sea bottom. Although little effort was made in the majority of samples to identify the various pecies eaten, the list of animals preyed upon is nevertheless extensive. Many of the individual organisms have, owever, been identified only on fairly rare occasions — a feature which is also characteristic of the feeding f other species of fish in Scottish waters — for example, haddock (Ritchie, 1937), whiting (Jones, 1954) and emon sole (Rae, 1956). Nevertheless cod of 21 cm and over certainly exhibit a remarkably wide range of redation within the two main groups, decapod crustaceans and fish. This arises to some extent from the bility of the cod to thrive under such a variety of natural conditions, ranging from the relatively fresh and hallow water of the Scottish river estuaries, to the more saline conditions on the edge of the Atlantic shelf. t has already been observed that even in the relatively limited area of the North Sea changes in the composiion of the food are recognised in passing from south to north. Thus shallow water types such as *Corystes* and *olea* give way to deeper water types such as *Geryon, Munida* and *Gadus esmarkii*.

The food of cod has been studied on many fishing grounds, so that proceeding beyond the North Sea to eland (Meschkat, 1936; Brown and Cheng, 1946), East and West Greenland (Jensen and Hansen, 1931; ersen, 1936) and Bear Island and the Barents Sea (Brotskaya, 1931; Zatsepin and Petrova, 1939; Brown and heng, 1946; Graham *et al,* 1954) changes in the composition of the food continue to be observed with the ppearance of types such as *Mallotus, Sebastes* and other northern and arctic forms and the disappearance of ore southerly species such as *Limanda, Microstomus* etc. Another feature of the food in some arctic regions is e frequency with which the larger cod occasionally eat the small members of their own species (Graham *et al,* 954); as already observed (p. 51) this rarely occurs in Scottish waters although it has been observed in Danish aters (Poulsen, 1931) and in the Baltic (Naumov, 1958). It is interesting, however, to note the occurrence of rring, sand eels and *Eupagurus* in the lists of organisms eaten on most grounds. In certain areas the results seem indicate a somewhat greater predation on molluscs, polychaetes and echinoderms than in Scottish waters. The od of cod on most northern grounds differs, however, from that in British waters by reason of the predation planktonic organisms (Jensen and Hansen, 1931; Graham *et al,* 1934; Kiselev, 1960). These include a variety animals, including euphausiids, cephalopods, the pteropod *Limacina* and ctenophores, which clearly suggest pelagic feeding habit. Further evidence of pelagic feeding is provided by the predation of cod on pelagic hes, some of them characteristically deep-water forms, such as myctophids, *Lampanyctus, Chauliodus, omias,* etc. (Iversen, 1936). In some respects this gives cause for regarding the cod as omnivorous, but it is rhaps preferable to consider these characteristics as evidence of the cod's ability to adapt itself with success to rying ecological conditions.

Vertical movements of cod at Bear Island have been described by Trout (1957) and off Newfoundland by empleman and Fleming (1962). Brunel (1964) reviewed the evidence and identified two types of vertical nigration" — short diurnal movements associated with the change from daylight to dark and vice-versa, d longer annual periods when cod lead an extended pelagic existence in mid-water. The significance of ese vertical "migrations" is not fully understood but they would appear to be linked with ecological conions and thus associated with feeding. Horsted and Smidt (1964) also record horizontal migrations of cod the west coast of Greenland in which the movement of the fish was observed by the appearance of their rsal fins at the surface of the sea in calm weather.

Although no reliable evidence of cod feeding away from the sea bottom has been obtained from the Scotsh area, the preponderance of pelagic fish types in many samples of stomachs certainly indicates this possiity. It must be recalled that almost without exception the material on which the present investigations are sed was largely procured by demersal trawl using a lower headline than is normally employed in modern wling practice. The preponderance of pelagic species in the food of the cod caught by Aberdeen trawlers in late 1950s (page 57) seems to suggest pelagic feeding, especially since the headline by this time tended to

be higher. Moreover it is possible that the cod, if they were caught on the bottom, may have descended after feeding in the upper water layers. However, the almost complete absence of planktonic forms in the food of cod of 21 cm and over in Scottish waters certainly suggests a marked difference in the feeding habits of cod compared with some northern regions.

COMPETITION FOR FOOD BETWEEN COD AND OTHER SPECIES

Any investigation of the food of fishes inevitably leads to a consideration, however brief, of the competition they encounter from other species in their quest for their favoured food types. Papers dealing with the food of all species in certain areas (Todd, 1905, 1907; Smith, 1889–1892) reveal varying degrees of competition between different species, but in a widespread fish such as the cod, the nature and extent of the competition can only be fully appreciated through a comprehensive study of its food throughout the region and comparison with similar studies of the food of other species. Unfortunately, relatively few detailed accounts of the food of individual commercially important fishes in the Scottish area have so far been published. Those which have appeared include haddock and plaice (Ritchie, 1937, 1938), whiting (Jones, 1954), lemon sole (Rae, 1956) and megrim (Rae, 1963). Of these the haddock is by far the most abundant species in the Scottish area and might well be regarded as a likely competitor with the cod. Ritchie and others have shown, however, that the haddock is mainly a mixed feeder on benthic types, so that competition with the cod is relatively slight. Nevertheless both fishes feed heavily on sand eels though not at the same time or place.

Jones has shown that the whiting feeds predominantly on crustaceans and fish. In this respect, and in its semi-pelagic feeding habit, the fish would seem to resemble the cod fairly closely. Young herring, sand eels, whiting and *Gadus esmarkii* are all important items in the food of both species, although the smaller average size of the whiting tends to limit the size of the fish it eats. Similarly, while cod of 21–50 cm prey heavily on decapod crustaceans, including both reptant and natant types, whiting of the same size concentrate more on a rather smaller size of crustacean, including euphausiids and natant decapods such as the crangonids and pandalids.

Despite the common interest of both cod and whiting in certain species of fish and crustaceans, observations on Scottish research ships have frequently suggested that competition for food is not always so obvious. To illustrate this, the common items in the stomach contents of cod and whiting taken in research vessel trawl catches in 1925, 1930 and 1935 have been listed in Table XLII. For comparison, mainly fish of approximately the same size have been considered. Although both cod and whiting occasionally preyed on the same food types, the remarkable feature of these records is the frequency with which the two species preyed on different types. This could of course arise from the whiting and cod occupying different areas of the ground covered by the trawl during the one-hour haul, but whether this is the explanation or not, it would appear that competition for food is not so intense as might be expected.

Somewhat similar views have been expressed by the author in respect of competition between codling and megrim (Rae, 1963). Although young cod and megrim have shown a joint interest in preying on crangonids, pandalids and *Gadus esmarkii* it has also been observed that these fish are seldom present in concentrations on the same grounds, so that direct active competition is comparatively rare.

Competition for food between cod and plaice is confined mainly to predation on sand eels, but the two species are rarely present on the same grounds in any number. Although the lemon sole is predominantly a polychaete feeder, this species frequently eats the smallest juvenile eupagurids — a type which in their more mature forms provide an appreciable share of the food of cod.

Studies of the food of turbot in Scottish waters (unpublished) reveal sand eels, herring and *Gadus esmarkii* as three of the most important food types for this fish. This suggests the turbot's common interest with the cod, and indeed on Turbot and Aberdeen Banks during the spawning of turbot, the two species are frequently taken together by Aberdeen trawlers. Although this indicates a degree of direct active competition for the available food it must be emphasised that this is both seasonal and local. Elsewhere in Scottish waters the turbot is sufficiently rare as to cause little competition with cod. Although the food of other commercially valuable fish is imperfectly known, it is clear from observations on Scottish research vessels that many species prey on sand eels. On sandy bottoms various species of *Raia* feed almost exclusively on *Ammodytes* while lythe

TABLE XLII

COMPARISON OF FOOD OF COD AND WHITING FROM INDIVIDUAL HAULS

Month	Area	Species	No.	Range cm	Food
ear 1925					
pril	E15	cod	6	20–44	crustaceans (3), empty (3);
		whiting	40	20–50	*Gadus esmarkii* (10), empty (30);
„	C13	cod	35	19–30	herring (1), goby (1), shrimps (7), *Hyas* (5), crabs (2), crustaceans (3), molluscs (1), rest empty;
		cod	10	33–60	whiting (5), *Hyas* (2), crustaceans (1), empty (3);
		whiting	30	23–35	herring (2), small whiting (10), empty (18);
„	B12	cod	12	20–37	shrimps (2), *Hyas* (3), *Eupagurus* (2), crustaceans (2), ophiuroids (1), whiting (1), empty (2);
		whiting	37	22–32	small whiting (7), empty (30);
„	A14	cod	30	24–30	*Hyas*, *Eupagurus*, molluscs, annelids, sprats, *Lumpenus;*
		cod	18	31–69	*Portunus*, *Hyas*, *Aphrodite*, c. dab, l.r. dab, other fish;
		whiting	49	23–40	sprats, *Lumpenus*, other fish;
ay	C13	cod	7	25–90	whiting, *G. esmarkii*, haddock, *Portunus*, crustaceans, annelids;
		whiting	8	25–41	fish, whiting;
,	B11	cod	12	20–42	*Portunus* (6), *Eupagurus* (2), shrimps (1), *Hyas* (2); *Portunus* (1), sipunculid;
			3	68–94	fish, *Lumpenus;*
		whiting	106	17–33	herring;
igust	D16	cod	6	27–73	haddock, sand eel, herring, *Nephrops;*
		whiting	50	20–42	mackerel, sand eels, *T. esmarkii*, whiting;
ptember	D14	cod	13	23–38	*Hyas*, *Portunus;*
		whiting	47	24–41	small herring, *G. esmarkii;*
„	C19	cod	6	23–49	dabs (1), *Portunus* (1), *Eupagurus* (1), crustaceans (4), *G. esmarkii* (4);
		whiting	50	22–34	small herring, *G. esmarkii;*
„	B20	cod	2	30–45	*Crangon*, *G. esmarkii;*
		whiting	6	30–40	herring, *G. esmarkii;*
ctober	A11	cod	25	25–75	whiting, shrimps, *Portunus*, mollusc;
		whiting	50	20–32	herring, sprats, shrimps;
„	B11	cod	20	26–50	*Nephrops*, *Hyas*, shrimps, fish;
		whiting	20	20–37	herring, shrimps;
„	C10	cod	13	22–32	shrimps, crabs;
		whiting	50	19–35	mackerel, whiting;
„	D9	cod	23	22–38	crabs;
		whiting	50	20–35	mackerel, *Belone* (1);
ar 1930					
ril	YY9	cod	29	44–80	*Gonoplax*, *Pasiphaea*, *Portunus*, *Nephrops*, *Corystes*, *Eupagurus*, *Hyas*, *Aphrodite;*
,	YY9	whiting	50	21–44	herring, sprats, *Gonoplax*, *Pasiphaea*, *Meganyctiphanes;*
,	WW10	cod	25	56–107	*Nephrops* (13), *Gonoplax* (1), *Aphrodite* (5), fish (1);
		whiting	27	26–44	*G. esmarkii;*
ptember	A11	cod	25	24–65	*Pandalus* (4), *Portunus* (7), *Eupagurus* (2), *Corystes* (1), fish (1), gunnel (2), empty (10);
		whiting	124	19–31	most feeding on small clupeoids;
„	B11	cod	8	23–60	*Portunus* (2), *Crangon* (2), other crustaceans (1), fish (1);
		whiting	100	18–31	most feeding on clupeoids (8–9 cm);
„	B11	cod	38	23–68	*Portunus* (30), crustaceans (6), *Eupagurus* (1), fish (3), l.r. dab (1), *annelids* (1);

TABLE XLII (*continued*)

Month	Area	Species	No.	Range cm	Food
Year 1930					
April		whiting	28	21–32	clupeoids (3), goby (1), other fish (2), *Crangon* (2 amphipods (1);
„	B11	cod	24	22–72	*Nephrops* (11), *Eupagurus* (2), *Crangon* (3), *Galath* (1), fish (1), *Aphrodite* (2);
		whiting	114	19–29	50 per cent on sprats and herring, others empty
October	G11	cod	6	25–40	*Eupagurus* (2), *Pycnogonum* (2), *Crangon* (1);
		whiting	66	20–32	half on mackerel (12 cm);
„	H11	cod	5	19–28	*Eupagurus* (2), empty (3);
		whiting	140	20–36	all feeding on mackerel (11–13 cm) one on herrin
„	D9	cod	9	22–45	*Eupagurus* (5), *Portunus* (1), *Crangon* (1), emp (3);
		whiting	247	21–38	c.50 per cent on mackerel (c.14 cm);
Year 1935					
October	A17	cod	20	36–63	sand eels (13), lemon sole (1), *Lumpenus* (1), f (1), *Pandalus* (8), *Munida* (7), *Portunus* (4);
		whiting	1	39	*G. esmarkii;*

saithe, hake and dogfish (both *Squalus* and *Scyliorhinus*), depending on the nature of the sea bottom and t composition of the local animal communities, also prey on sand eels from time to time. It is evident, therefo that the cod may have to contend with some competition for its principal food type, the sand eel, although n necessarily always at the same time or in the same place.

Yet another important food of the cod, *Nephrops norvegicus*, has been shown by Thomas (1965) to be ea by various species of fish. Although more local in its distribution than the sand eel, *Nephrops* has been identif in the stomachs of at least 15 species of fish in the Scottish area. Of these cod has been found to be the cl predator, although the lesser spotted dogfish (*Scyliorhinus caniculus*) is a remarkably close rival on grou where *Nephrops* is abundant. It should also be observed that in the author's experience the food of the les spotted dogfish in general resembles that of the cod more closely than that of any other species of fish in Scottish area. This is evident as regards both the composition of the food (predominantly fish and decap crustaceans, with molluscs, polychaetes and ophiuroids in smaller proportions) and the sizes of the individ organisms eaten.

SUMMARY

Numerous observations on the food of cod in Scottish waters from the early 1920s to 1965 have b analysed. Seasonal variations in the feeding of cod were studied from the numbers of empty stomachs corded monthly. It is evident that cod feed throughout the year, but after fairly intensive feeding in Jan and February a noticeable decline occurs in March and April, apparently during the spawning season. T is followed by vigorous feeding in May which reaches a peak in June or July, after which the numbers of em stomachs gradually increase to a maximum in September. In October and November feeding again appear increase slightly, to be followed by another decline in December. These conclusions are supported by obse tions on the fullness of the stomachs throughout the year.

Evidence of diurnal feeding habits suggests that cod may feed at any time throughout the twenty-f hours, but individual samples clearly indicate particularly heavy feeding at variable times. Examination of stomach contents tends to show dawn and dusk feeding habits. Reference is made to the retention of fo in the stomachs, as demonstrated by various investigators.

The composition of the food was considered on a local or regional basis with emphasis on two size-gro of cod — 21–50 cm and 51 cm and over. The food of the smallest codling, less than 21 cm, as shown by ot workers, consists almost entirely of small crustaceans. Fish of 21–50 cm continue to feed predominantly

crustaceans (mainly decapods), although with growth they increasingly eat more fish. Cod of 51 cm and over are in general mainly fish eaters, although in certain regions they may continue to prey heavily on decapod crustaceans, for example on *Nephrops norvegicus*. The food of cod also includes various types of molluscs, polychaetes (especially *Aphrodite*), ophiuroids, and, on rare occasions, other types such as gephyreans, nemerteans, anthozoans and ctenophores.

Regional differences have been demonstrated in the food of cod in Scottish waters. Two food types are of supreme importance — sand eels (*Ammodytes*), and Norway lobsters (*Nephrops*). The results are compared briefly with those from other regions in the North Atlantic. Feeding habits and possible competition for food with other species of fish caught on the same grounds are discussed.

REFERENCES

BROOK, G. 1886. Preliminary report on the food of the cod. *Rep. Fishery Bd Scotl.*, **4** (1885), 134-147.

BROTSKAYA, V. A. 1931. The feeding of the cod. Material and method. [In Russian with Englishs ummary] *Trudy gos. okeanogr. Inst.* No. 4, 20-35.

BROWN, W. W. *and* CHENG, G. 1946 Investigations into the food of the cod (*Gadus callarius* L.) off Bear Island, and of the cod and haddock (*G. aeglefinus* L.) off Iceland and the Murman coast. *Hull Bull. mar. Ecol.*, **3** (18), 35-71.

BRUNEL, P. 1965. Food as a factor or indicator of vertical migrations of cod in the western Gulf of St. Lawrence. *Spec. Publs int. Commn NW. Atlant. Fish.* No. 6, Contr. 439-448, C.2.

CALDERWOOD, W. L. 1907. The life of the salmon. Arnold, London. 151 pp.

ELMHIRST, R. 1926. Notes on fishes from the Firth of Clyde. *Scott. Nat.* No. 161, 151-158.

FRASER, J. H. 1960. Plankton investigations from Aberdeen in 1958. *Annls biol., Copenh.*, 15; 57-58.

GRAHAM, M. 1924. The annual cycle in the life of the mature cod in the North Sea. *Fishery Invest., Lond.*, Ser. 2, **6** (6), 77 pp.

GRAHAM, M. *et al.* 1954. Report on research from the " Ernest Holt " into the fishery near Bear Island, 1949 and 1950. *Fishery Invest., Lond.*, Ser. 2, **18** (3), 87 pp.

GUDJONSSON, T. 1953. Laxamerkingar 1947-51. *Náttúrufraedingurinn*, **23**, 178-187.

HENDERSON, G. T. D. 1961. Contribution towards a plankton atlas of the North-eastern Atlantic and the North Sea. Pt. 5. Young fish. *Bull mar. Ecol.*, **5** (42), 105-111.

HORSTED, S. A. *and* SMIDT, E. 1965. Remarks on effect of food animals on cod behaviour. *Spec. Publs int. Commn. NW. Atlant. Fish.* No. 6, 435-437, Contr. C.1.

IVERSEN, T. 1936. Sydøstgrønland, Jan Mayen. *FiskDir. Skr., Ser. Havundersok.*, **5** (1), 171 pp.

JENSEN, A. S. *and* HANSEN, P. M. 1931. Investigations on the Greenland cod (*Gadus callarius* L.) *Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer.*, **72** (1), 41 pp.

JONES, R. 1954. The food of the whiting and a comparison with that of the haddock. *Mar. Res.*, 1954 (2), 34 pp.

JOHNSTONE, J., SCOTT, A. *and* SMITH, W. C. 1924. Report on I. The Irish Sea cod fishery. II. The cod as a food fish. III. Parasites and diseases of cod. *Fishery Invest., Lond.*, Ser. 2, **6** (7), 27 pp.

KISELEV, O. N. 1960. Observations on fish behaviour by means of underwater technique in the Barents Sea. [In Russian with English summary] VNIRO and PINRO. *Soviet Fish. Invest. North European Seas.* Moscow 457-61.

LAMONT, J. M. 1964. Plaice investigations in Scottish waters. 1. Size-composition of the stocks. *Mar. Res.*, 1964 (1), 29 pp.

MACER, C. T. 1966. Sand eels (*Ammodytidae*) in the south-western North Sea; their biology and fishery. *Fishery Invest., Lond.* Ser. 2, **24** (6), 55 pp.

MESCHKAT, A. 1936. Untersuchungen über den Aufbau der Kabel jau nahrung im Bereich der Vestmannainseln, *Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer*, **99** (3), 19 pp.

NAUMOV, V. M. 1958. Nutrition of cod in the Baltic sea. *Trudy vses, nauchno-issled. Inst. morsk. ryb. Khoz. Okenogr.*, **34**, 127-132.

RIGGINS, D. J. 1959. Investigations on predators of salmon smolts and parr. *Rep. Salm. Res. Trust Ireland.* (1958.) Appendix 1.

SOULSEN, E. M. 1931. Biological investigations upon the cod in Danish waters. *Meddr Kommn Danm. Fisk.-og Havunders., Fisk.*, **9** (1), 148 pp.

SOWLES, P. M. 1958. Studies of reproduction and feeding of Atlantic cod (*Gadus callarias* L.) in the south-western Gulf of St Lawrence. *J. Fish. Res. Bd Can.*, **15**, 1383-1402.

TAE, B. B. 1956. The food and feeding habits of the lemon sole. *Mar. Res.* 1956 (3), 32 pp.

— 1963. The food of the megrim. *Mar. Res.* 1963 (3), 23 pp.

— 1964. Early development of cod roe. *Scott. Fish. Bull.*, No. 22, 18.

TAIT, D. F. S. *and* ADAMS, J. A. 1965. The food and feeding of *Trisopterus esmarkii* (Nilsson) in the northern North Sea. *Mar. Res.*, 1965 (3), 28 pp.

RITCHIE, A. 1937. The food and feeding habits of the haddock (*Gadus aeglefinus* L.) in Scottish waters. *Scient. Invest. Fishery Bd Scotl.*, 1937 (2), 94 pp.

—— 1938. Preliminary observations on the food of the plaice, *Pleuronectes platessa*) in Scottish waters. *Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer.* **107**, 49-56.

SMITH, W. R. 1889. On the food of fishes. *Rep. Fishery Bd Scotl.* (1888) **7** (3), 222-258.

—— 1890. On the food of fishes. *Rep. Fishery Bd Scotl.* (1889), **8** (3), 230-256.

—— 1891. On the food of fishes. *Rep. Fishery Bd Scotl.* (1890), **9** (3), 222-242.

—— 1892. On the food of fishes. *Rep. Fishery Bd Scotl.* (1891), **10** (3), 211-231.

STANEK, E. 1964. Biological characteristics of cod (*Gadus morhua* L.) caught in the southern Labrador and Newfoundland fishing grounds in the winter of 1963. *ICNAF Ann. Meet.* 1964. Doc. No. 28.

STRZYZEWSKA, K. 1959. Feeding and food of the southern Baltic cod. *ICES C. M.* 1959, *Gadoid Committee.* Doc. No. 26.

TARVERDIEVA, M. I. 1962. Some data on the feeding of the Barents Sea cod *Gadus morhua morhua* L. in experimental conditions. *Vop. Ikhtiol.*, **2**, (4) (25) 703-716.

TEMPLEMAN, W. 1965. Some instances of cod and haddock behaviour and concentrations in the Newfoundland and Labrador areas in relation to food. *Spec. Publs int. Commn NW. Atlant. Fish., No.* 6, 449-461, Contr. C3.

TEMPLEMAN, W. *and* FLEMING, A. M. 1962. Cod tagging in the Newfoundland area during 1947 and 1948. *J. Fish. Res. Bd Can.*, **19** (3), 445-487.

THOMAS, H. J. 1965. The white fish communities associated with *Nephrops norvegicus* (L.) and the by-catch of white fish in the Norway lobster fishery, together with notes on Norway lobster predators. *Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer*, **156** (29), 155-160.

TODD, R. A. 1905. Report on the food of fishes collected during 1903. *Rep. N. Sea Fish. Invest. Comm.*, **1** (S. Area), 227-287.

—— 1907. Second report on the food of fishes (North Sea, 1904-05) *Rep. N. Sea Fish. Invest. Comm.*, **2** (S. Area) (1), 49-163.

TROUT, G. C. 1957. The Bear Island cod: migrations and movements. *Fishery Invest., Lond.* Ser. 2, **21** (6), 51 pp.

WIBORG, K. F. 1948. Some observations on the food of cod (*Gadus callarias* L.) of the O-II Group from deep water and the littoral zone in northern Norway and from deep water at Spitzbergen. *FiskDir. Skr., Ser., Havundersok.*, **9** (4), 19 pp.

—— 1949. The food of cod (*Gadus callarias* L.) of the O-II group from deep water in some fjords of northern Norway. *FiskDir. Skr. Ser. Havundersok.*, **9** (8), 27 pp.

ZATSEPIN, V. I. *and* PETROVA, N. S. 1939. The feeding of commercial shoals of cod in the southern Barents Sea. *Trudy polyar. nauchno-issled. Inst. morsk. ryb. Khoz. Okeanogr.* **5**, pp. 176.

APPENDIX

LIST OF GENERA AND SPECIES IDENTIFIED IN THE FOOD OF COD, WITH PLACE OF OCCURRENCE INDICATED BY STATISTICAL RECTANGLES, A14, C13, etc. (SEE FIG. 1)

CRUSTACEA

DECAPODA—REPTANTIA

Eupagurus sp.: A14, 15, 16, 17; Firth of Forth, St Andrews Bay, Bell Rock, E. of Isle of May; Aberdeen Bay; B14, 15, 16, 17, 19, 20; C9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20; D8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21; E8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21; F7, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20; G4, 7, 8, 9, 10, 11, 14, 15, 16, 17, 19, 20; H4, 6, 7, 9, 10, 11, 12, 13, 14, 15; J6, 8, 9, 10, 11, 13; K9, 11; M12; ZZ9, 10, 16, 17; YY9, 15, 16, 18; XX10, 11, 13; VV10, 11.

E. prideauxi Leach: Aberdeen Bay.

E. bernhardus (L.): C11, 13; G8; H15; XX9.

Portunus sp.: A14, 15, 16, 17; Firth of Forth, St Andrews Bay, Bell Rock, E. of Isle of May, off St Abbs; Aberdeen Bay; B12, 14, 15, 16, 17; C9, 10, 11, 12, 13, 15, 16, 17, 18, 19; D9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21; E8, 13, 14, 18, 19, 21; F6, 9, 12, 19; G6, 7, 8, 9, 10, 16, 18, 20, 21; H6, 7, 9, 11, 12, 13, 14, 15, 16; J6, 8, 11, 12, 13; K9, 12; L8; M11; ZZ10, 16, 17; YY9, 15, 16, 17, 18; XX10, 11, 14, 15, 16; VV11, 12, 14, 16; UU10, 12.

P. holsatus Fabricius: Aberdeen Bay, C13.

P. depurator (L.): A16; Firth of Forth; Aberdeen Bay; C13.

Hyas sp.: A14, 15, 16; Firth of Forth, Bell Rock, E. of Isle of May; Aberdeen Bay; B14, 15, 16, 17, 19; C10, 11, 12, 13, 14, 17, 18, 19; D11, 12, 13, 16, 17, 18, 19, 20; E7, 8, 11, 12, 13, 14, 18, 19; F14, 17, 18; G15, 16, 17, 19; H6, 11, 13, 14, 15; J13; ZZ10, 16, 17; YY8, 9, 10, 15, 16; XX9, 10, 12, 13, 14, 16; VV11, 12.

H. coarctatus Leach: Aberdeen Bay; C11, 14, 17; D16; H15.

H. araneus (L.): Aberdeen Bay; C17.

Atelecyclus sp.: A14, 15, 16; Firth of Forth, E. of Isle of May; Aberdeen Bay; B14, 15, 16, 19; C10, 13, 15, 16; D13, 16, 17, 20, 21; E13; F19, 20; G18, 19; ZZ16, 17; YY9, 15; XX15; VV11, 12, 16; UU12.

Corystes cassivelaunus (Pennant): Firth of Forth, St Andrews Bay, Bell Rock, E. of Isle of May; Aberdeen Bay; C11, 13; D13, 20; E7, 9, 13; F6, 7; G6, 13; H6, 7; J6, 8; ZZ16; YY9; WW11; VV10.

Inachus sp.: XX14.

Pinnotheres sp.: Firth of Forth; B19.

Porcellana sp.: H9; K9; L8.

P. longicornis (L.): Aberdeen Bay; XX9.

P. platycheles (Pennant): Aberdeen Bay.

Cancer pagurus L.: Aberdeen Bay; B14; D12; G8; YY14.

Carcinus maenas (L.): Aberdeen Bay; B15; C12; ZZ10.

Geryon tridens Krøyer: B14; C16; D15, 16, 17; E13, 16, 17, 18, 19; F15, 17, 20; G17; H18; YY15.

Ebalia sp.: B16; C13; D13, 16; E13; ZZ16; YY9.

Lithodes maia (L.): D19, 20; E17; G16; WW15; VV12.

Gonoplax sp.: D15, 18; YY9; XX13; WW10; VV10.

G. rhomboides (L.) = *G. angulata:* A15; B14, 15; D15; ZZ9, 10; YY9; VV10.

Xantho sp.: A16; Aberdeen Bay; B19; D16; F17; G18; YY18; WW13.

X. florida Leach: VV14.

Stenorhynchus sp.: A16; Aberdeen Bay; C13, 14; D12, 20; ZZ16, 17; XX10, 13; UU12.

S. tenuirostris (Fabricius): C13; ZZ17.

Bathynectes superba da Costa: VV13.

Nephrops norvegicus (L.): A14, 15, 17; Firth of Forth; Bell Rock; E. of Isle of May; B10, 14, 15, 16; C9, 10, 11, 13, 15, 16; D14, 15, 16, 17, 18, 19, 20; E14, 15, 16, 18, 19; F14, 15, 18, 19, 20, 21; G17, 18, 19; H16, 17, 18; ZZ9, 10; YY9, 10, 13, 14, 15, 16; XX11, 13, 14, 15; WW10, 11, 12, 13; VV10, 11, 14; UU12, 13.

Galathea sp.: A14, 15, 16, 18, Firth of Forth, Bell Rock, E. of Isle of May, off St Abbs; Aberdeen Bay; B14, 16, 19, 20; C9, 10, 11, 12, 13, 14, 17, 19, 20; D13, 18, 20, 21; E12, 13, 19, 20; F6, 17, 19, 20; G16, 17, 20; H11, 15, 16; ZZ9, 10, 16, 17; YY14, 15, 16, 17; XX9, 13, 14, 15, 16; WW11; VV12, 14, 15, 16; UU13.

G. squamifera Leach: XX9.

Munida sp.: A14, 15, 16, 17; Firth of Forth, St Andrews Bay, Bell Rock; Aberdeen Bay; B14, 16, 19, 20; C12, 13, 14, 17, 20; D19, 20, 21; E12, 13, 21; F17, 21, 22; G19; H15, 18; ZZ9, 10, 16, 17; YY9, 10, 14, 16, 17, 18; XX9, 10, 12, 13, 14, 15, 17; WW11, 15; VV12, 14, 15, 16; UU10, 12, 13, 14.

M. rondeletti Mihi: C13.

Calocaris macandreae Bell: B14; ZZ10; XX11, 15; WW13.

DECAPODA—NATANTIA

Crangon sp.: A14, 15, 16; Firth of Forth, St Andrews Bay, Bell Rock, off St Abbs; Aberdeen Bay; B14, 15, 16, 19; C9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20; D8, 9, 10, 12, 13, 15, 16, 18, 20; E10, 13, 14, 15, 16, 19; F11, 17; G11, 14, 17, 18; H6, 9, 14, 15; L8; ZZ9, 10, 16; YY9, 15, 17, 18; XX10, 13, 15, 16.
C. vulgaris Fabricius: Aberdeen Bay.
C. allmani Kinahan: A16; Firth of Forth; Aberdeen Bay; H15; YY15.
Pandalus sp.: A14, 15, 16, 17; Firth of Forth, St Andrews Bay, Bell Rock, E. of Isle of May, off St Abbs; Aberdeen Bay; B14, 15, 16, 17, 19; C10, 11, 12, 13, 14, 15, 16, 17, 18, 19; D10, 12, 13, 14, 15, 16, 18, 19, 20; E13, 14, 15, 17, 19, 20, 21; F16, 17, 18, 19, 20, 22; G15, 17; H11, 12, 15, 19; J13; ZZ9, 10, 16; YY9, 10, 13, 14, 15, 16, 17, 18; XX9, 10, 11, 13, 15, 16, 17; WW13; VV15, 16; N.W. Ireland.
P. montagui Leach: Aberdeen Bay; C11, 15; XX15.
Pasiphaea sivado (Risso): YY9.
Hippolyte sp.: A16; Firth of Forth, E. of Isle of May; Aberdeen Bay; B14; C10, 13; D20; E13, 14, 19; G15; ZZ16; YY10.
Pontophilus spinosus (Leach): B19; C13.
Spirontocaris sp.: H15.
S. spinus (Sowerby): C13.
Nika edulis Risso: Firth of Forth; B19; C13; D14; VV10.

PYCNOGONIDA

Pycnogonum littorale (Strøm): G11.

EUPHAUSIACEA

Meganyctiphanes norvegica (M. Sars): D20, 21.

MYSIDACEA

Schistomysis ornata (G. O. Sars): H15; J13.

ISOPODA

Idotea linearis (Pennant): Aberdeen Bay.
Astacilla sp.: H15.
A. longicornis (Sowerby): H15.
Eurydice sp.: Firth of Forth.

CIRRIPEDIA

Balanus sp.: C13.

PISCES

Ammodytes sp.: A14, 15, 16, 17, 18; Firth of Forth; St Andrews Bay; Bell Rock; E. of Isle of May; Aberdeen Bay; B14, 15, 16, 17; C11, 13, 14, 15, 17, 18, 19; D9, 13, 15, 20, 21; E13, 19, 21; F6; G6, 8, 13, 19; H6, 7, 15; J11; ZZ10, 16, 17; YY9, 15, 16, 17; XX10, 11, 13, 15, 16.
Gadus sp.: A14, 16, 17; Firth of Forth; E. of Isle of May; Aberdeen Bay; B14, 15, 17; C9, 11, 13; D13, 15, 16, 17, 20; E7, 13, 15, 19, 21, 22; F16, 17, 18, 19, 20, 21, 22; G15, 16, 17, 18, 19; H11, 13, 18; J8, 11, 13; ZZ10, 16; YY9, 13, 14, 15; XX9, 10, 13, 15, 16; WW10, 11, 15; VV12, 14, 15, 16; UU9, 13.
G. merlangus L. = *Merlangius merlangus:* A14, 15, 16, 18; Firth of Forth; St Andrews Bay; Bell Rock; E. of Isle of May; Aberdeen Bay; B14, 15; C9, 10, 11, 12, 13, 17; D13, 15, 17; E13, 14, 18, 19; F16, 18, 20; G13, 15, 16, 19; H6, 10, 11, 13, 15, 17; J8, 13; ZZ10; YY9; XX11.
G. aeglefinus L. = *Melanogrammus aeglefinus:* A14, 15; Firth of Forth; Aberdeen Bay; B14; C12, 13, 14, 19; D13, 19, 20, 21; E13, 19; F16, 19, 20, 21; G15, 18, 20, 21; H15; J13; ZZ10; YY16; XX15, 16; WW15.
G. esmarkii Nilsson = *Trisopterus esmarkii:* A15, 17; Firth of Forth; B14, 19, 20; C11, 13, 17, 20; D10, 14, 15, 16, 17, 18, 19, 20, 21; E13, 14, 15, 16, 18, 19; F15, 17, 22; G15, 16, 17, 18, 19, 20; H14, 15; J13; ZZ10, 16; YY15, 16; XX12, 14, 15; WW10, 12; VV11.
G. callarias L. = *G. morhua:* Firth of Forth; C13; F7.
G. poutassou (Risso) = *Micromesistius poutassou:* E15, 22; F22; WW10.
G. minutus L. = *Trisopterus minutus:* Aberdeen Bay; B15, 16; D20; ZZ17; XX9; VV14; UU10, 12; Rockall Bank.
Gadiculus argenteus Guich: G20; H17.
Molva molva (L.): D19.
Urophycis blennoides (Brünnich): UU12.
Onos sp.: C11, 12; D15, 20; E9, 16; F20; ZZ9.
O. cimbrius (L.): Firth of Forth, E. of Isle of May; Aberdeen Bay; B14; C13; D16; YY10, 14; XX9, 15; WW13.
Scomber scombrus L.: C12, 21; D15, 20, 21; E13, 15, 17; F17, 19, 20, 21; G15, 16, 17; H15; J13; YY16; WW10; VV14; UU14.

upea harengus L.—including spawn: A14; Firth of Forth; St Andrews Bay; Bell Rock; E. of Isle of May; Aberdeen Bay; B14, 16, 17; C10, 11, 13, 16, 18, 19, 20, 21; D10, 13, 14, 15, 16, 17, 18, 19, 20, 21; E8, 11, 13, 14, 15, 16, 18, 19, 21; F9, 12, 15, 17, 18, 19, 20, 22; G10, 17, 19, 20; H7, 15, 18; J13; K12; ZZ9, 10, 18; YY9, 10, 15; XX12, 15, 16; VV12, 13, 15; UU13, 14.
sprattus L.: A14; Firth of Forth; St Andrews Bay; Bell Rock; E. of Isle of May; Aberdeen Bay; B14; C9, 11; E13; J8, 9; YY9.
manda limanda (L.): A14, 15, 16, 17; Firth of Forth; St Andrews Bay; Bell Rock; Aberdeen Bay; B14, 15; C11, 12, 13, 17; D9, 20; E11, 13, 19; F7, 19; G10, 11, 15, 17, 19; H7, 10, 13, 15; J13; ZZ17; YY15.
ppoglossoides platessoides (Fabricius): A14; Firth of Forth; Bell Rock; E. of Isle of May; Aberdeen Bay; B10, 14, 15, 16, 17; C10, 11, 13, 15; D13, 14, 15, 16, 17, 18, 19, 20; E11, 13, 14, 15, 17, 18, 19, 21; F12, 17, 18, 19, 20, 22; G10, 13, 15, 16, 17, 18, 19; H6, 10, 13, 15, 18; J13; ZZ10; YY15; XX13.
icrostomus kitt (Walbaum): A14, 15, 17; Firth of Forth; Aberdeen Bay; B14, 15, 16; C13; D13, 20, 21; E13; XX15; WW10; VV11, 14, 16; UU12.
yptocephalus cynoglossus (L.): A14; D16, 19; F19; G15, 17, 20; J13, ZZ10.
pidorhombus whiff-iagonis (Walbaum): D20.
atichthys flesus (L.): A14.
euronectes platessa L.: St Andrews Bay; Aberdeen Bay.
lea sp.: G8; H6.
icrochirus boscanion (Chabanaud) = *Solea lutea:* A14; H6.
rynorhombus (*Zeugopterus*) *norvegicus* (Günther): B14; C17; YY16.
igla gurnardus L.: A14, 15; Firth of Forth; Aberdeen Bay; B14; C11; D21; E19; G14, 18; J13.
arhichas lupus L.: H15.
erluccius merluccius (L.): Off St Abbs Head; B14; D19; H18; XX13, 15; WW10.
clopterus lumpus L.: YY9.
phius piscatorius L.: H18.
gellus centrodontus (De la Roche): N.W. Ireland.
lmo trutta L.: ZZ10; B14; Donegal Bay (see page 52).
lmo salar L.: B14 (see page 52).
onus cataphractus (L.): A14, 15, 16; Firth of Forth, St Andrews Bay; Aberdeen Bay; B14, 15, 16; C11; G15; H15; ZZ16; XX9.
llionymus sp.: B15; C19; D12, 14, 20; E7, 21; F6, 7, 22; H7; ZZ17; YY16, 17; XX13, 15, 16, 17; WW15; VV15.
lyra L.: A14, 15, 16; Firth of Forth, St Andrews Bay, Bell Rock, E. of Isle of May; Aberdeen Bay; B14, 15; C12, 13, 15; D13, 14, 15; E14; ZZ9, 10, 16, 17; YY9.
maculatus Rafinesque: C11; YY9.
gentina sphyraena L.: C13; D20; E15; F20, 22; YY9; WW12; UU10, 13.
olis gunnellus (L.): A14; Firth of Forth; Aberdeen Bay; B14; C12; YY9, 17.
irolophis galerita (L.): A14; D20.
inachia spinachia (L.): Inverness Firth.
ngathus acus L.: A14.
iglops murrayi Günther: B14; C12, 13, 19.
mpenus lampetraeformis (Walbaum): A16, 17; Firth of Forth, E. of Isle of May; B10, 14; C9, 10, 11, 13; ZZ9, 10.
padogaster bimaculatus (Bonnaterre): A16.
bius sp.: B14, 15, 16; C11, 12, 13; D20, 21; E13; YY9; XX13, 15; VV15; N.W. Ireland.
bius minutus Gmelin: Firth of Forth, St Andrews Bay; Aberdeen Bay.
ttus sp.—including spawn: Firth of Forth; Aberdeen Bay; XX9.
baris sp.: E. of Isle of May; C19.
achinus vipera Cuvier and Valenciennes: Aberdeen Bay.
arces viviparus (L.): Aberdeen Bay.
mmius sp.: B14.
achurus trachurus (L.) = *Caranx trachurus:* XX15.
bastes sp.: G17.
lia sp.—including ova: Aberdeen Bay; C13; D13, 20; E13, 19; G17; ZZ16, 17; YY17; XX15; UU10.
radiata Donovan: C10; H10.
naevus Muller and Henle: YY17; XX15.
batis L.: A14.
gliorhinus caniculus (L.)—including ova: D21; YY14; VV12.
oxine glutinosa L.: A14; F11, 15.

MOLLUSCA

GASTEROPODA

Trochus sp.: E. of Isle of May; C12.
Patella sp.: XX9.
Turritella sp. : A14; C11, 13; H6; ZZ10; XX13.
Natica sp.: A16.
N. montagui Forbes: H15.
Fusus sp.: Aberdeen Bay.
Buccinum sp.: Firth of Forth; B14; C13; D15, 20; E13; G13; H13; J13.
Scaphander sp.: C12.

SCAPHOPODA

Dentalium sp.: B19; C13; D20, 21; E14, 21.

LAMELLIBRANCHIATA

Nucula sp.: B15.
Glycimeris sp.: B16.
Modiolus sp.: XX9.
Mytilus sp.: Aberdeen Bay.
Pecten sp.: E. of Isle of May; G17; ZZ16.
Chlamys sp.: UU10.
C. opercularis (L.): ZZ17; YY9.
Lima sp.: XX9.
Cyprina sp.: B14.
Dosinia sp.: Aberdeen Bay.
Venus sp.: Aberdeen Bay.
Donax sp.: Aberdeen Bay.
Ensis (*Solen*) sp.: Aberdeen Bay; Firth of Forth; B15; G9; YY9.
Mya sp.: Aberdeen Bay.

CEPHALOPODA

Rossia macrosoma (Delle Chiage): ZZ16; XX14.
Sepiola sp.: A15, 16; E. of Isle of May, off St. Abbs; Aberdeen Bay; B14, 16; C13, 14; D13; WW11.
Loligo sp.: A14; Aberdeen Bay; B14; C13; D13, 20; E13, 14, 19; XX9.
Eledone cirrhosa (Lamarck): A16, 18; St. Andrews Bay, Bell Rock; Aberdeen Bay; B14, 16, 19; C13; E13; G15, 21; Z
16; YY9, 18; XX15, 16; WW10; UU13.

POLYCHAETA

Aphrodite aculeata L.: A14, 15, 16; Firth of Forth, St Andrews Bay, Bell Rock, E. of Isle of May; Aberdeen. F
B14, 15, 19; C9, 10, 11, 12, 13, 15, 16, 18; D9, 12, 13, 14, 15, 17, 19, 20; E13, 18, 19; F7, 9, 11, 17, 19; G8, 10,
18, 19; H6, 7, 10, 11, 13, 14, 15, 18; J6, 8, 11, 13; K9; L9; ZZ9, 10; YY9, 10, 14, 15; XX9, 10, 12, 13, 15, 16; WW
UU14.
Phyllodoce sp.: Firth of Forth, E. of Isle of May; G13; H15.
Nereis sp.: Firth of Forth.
Nephthys sp.: Firth of Forth; Aberdeen Bay; B16; C16; J13.
Glycera sp.: Aberdeen Bay; B14.
Arenicola sp.: Firth of Forth; Aberdeen Bay; C13.
Pectinaria sp.: Aberdeen Bay.

ECHINODERMATA

Asterias rubens L.—juvenile: B15.
Ophiothrix fragilis (Abildgaard): A16; Bell Rock, E. of Isle of May; Aberdeen Bay; XX9.
Amphiura sp.: Bell Rock.
Ophiura sp.: UU9.
Ophiura texturata Lamarck: Aberdeen Bay.
Ophiopholis aculeata (L.): Aberdeen Bay; B14, 15; D19; G20; XX9, 15.
Spatangus purpureus O. F. Müller: J13.

ANTHOZOA

Tealia sp.: Aberdeen Bay; C13.
Metridium sp.: ZZ10.

CTENOPHORA

Beröe: Firth of Forth, E. of Isle of May.

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